SCIENTIFIC OBSERVATION HOLE #4
KILAUEA EAST RIFT ZONE, HAWAII
SUMMARY REPORT OF DRILLING OPERATIONS

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General

The Scientific Observation Hole drilling project was designed to gather information for scientific research and provide information on the geothermal potential on the island of Hawaii. Core drilling was chosen due to the tremendous amount of additional information provided by the continuous core to geologists studying the volcanic evolution of the island. Knowledge of the geothermal resource will be enhanced from information gathered on mineralization, lithology, alteration and fracture permeability which cannot be provided by typical rotary drilling techniques.

Tonto Drilling Services was chosen as the drilling contractor. Tonto has had an excellent history of core drilling geothermal exploration holes and has invested in innovative equipment to accomodate the particular problems associated with core drilling high temperature holes. The drilling rig provided by Tonto for the SOH project is unique, it was built in Australia and is one of only two in existence. This particular piece of equipment has been extensively modified for geothermal work and to meet strict noise requirements mandated by the County of Hawaii.

A jack-up system permits elevating the rig and placing a 10.5 foot high substructure under the mast. The substructure carries the weight associated with drilling and serves as a working floor. To minimize noise, the mud pumps, mixing pumps and light plant are outfitted with hydraulic motors which are powered by the rig hydraulic system. This eliminates nearly all of the ancillary internal combustion engines associated with drilling operations. The rig engine, a GM 12V-7 (410 HP), is completely enclosed in a sound insulating compartment and outfitted with hospital type mufflers. Noise levels at the perimeter of the drill site are less than 65 dBA.

The main hoist has a lifting capacity of 88,000 pounds and the rotation head has a maximum output torque of 6,630 foot pounds. The maximum depth rating is variable, depending on the size of drill rods used, in the case of NQ rod which was used to complete SOH-4, the theoritical maximum depth is over 17,000 feet.

Drilling Operations

SOH-4 was spudded-in at 5 PM on December 12, 1989 and completed to a total depth of 6,562 feet on May 15, 1990 on the 142nd day of drilling operations. A brief summary of drilling activities is given below and graphically presented in Figure 10.

Table 1
SOH-4 Drilling Summary

Dates	Day #	Activity
12/13 - 12/14	1 - 2	Core 134mm 0 - 112 ft.
12/14 - 12/21	2 - 8	Open hole to 17-1/2" 0 - 114 ft.
12/22 - 1/2	N/A	Christmas break
1/3 - 1/5	9 - 11	Run and cement 13-3/8" casing and nipple up BOPE.
1/6 - 1/13	12 - 19	Core 101mm 114 - 992 ft.
1/13 - 1/14	19 - 20	Survey, make up rotary drilling assembly.
1/15 - 2/14	21 - 51	Open hole to 12-1/4" 114 - 992 ft.
2/15 - 2/17	51 - 54	Run and cement 9-5/8" casing and nipple up BOPE.
2/17 - 3/1	54 - 65	Core 101mm 992 - 2,000 ft.
3/1 - 3/2	65 - 66	Survey, run sleeve, make up rotary drilling assembly.
3/2 - 3/11	66 - 75	Open hole to 8-1/2" 992 - 2,000 ft.
3/11 - 3/15	75 - 79	Run 7" casing, wait on HOWCO, cement, nipple up BOPE & drill out float equip.
3/16 - 4/25	80 - 121	Core HQ 2,000 - 5,290 ft.
4/25 - 4/27	121 - 123	Stick HQ rods & rig up for NQ.
4/27 - 5/16	123 - 142	Core NQ 5,290 - 6,562 ft. TD hole.
5/16 - 5/25	142 - 151	Survey, run injection test, lay down drill rods & rig down.

Drilling commenced by coring with 134mm (5.27 inch hole with 3.35 inch core) from the surface to 112 feet. Circulation was promptly lost at a depth of less than one foot. The hole was then opened to 17-1/2 inches in three passes with 8-1/2 inch, 12-1/4 inch and 17-1/2 inch hole openers. Total reaming time was 5 days. The hole had one or more doglegs due to the alternating hard/soft nature of the numerous thin basalt flows (averaging less than 10 feet in thickness) consisting of a few feet of competent basalt and several feet of interflow rubble and cinder. An unsuccessful attempt to run 13-3/8 inch casing was made on December 18. A 17-1/2 inch roller reamer was obtained and run behind the hole opener to straighten the hole on December 20 - 21. The site was secured on December 21 for Christmas break.

Operations resumed on January 3. The 17-1/2 inch drilling assembly was run to TD to check hole condition and 13-3/8 inch casing (K-55, 61 lb/ft, BT&C) was run open ended to TD. After bailing the hole dry, cementing was accomplished using local redimix (6 sack mix w/ 1/2 inch minus aggregate). After approximately one cubic yard of concrete was poured down the annulus, the casing was picked up off bottom several times to allow the cement to flow around the base of the casing and clean out any debris. The casing was then set back on bottom and the annulus filled with concrete to the surface.

On January 5 the blow out perevention equipment ("BOPE") was nippled-up. Equipment consisted of a 13-3/8 inch slip-on wellhead with two 2 inch flanged outlets, a 13-5/8 inch Type E double-gate preventer with pipe and blind rams, rotating head and 2 inch choke and kill lines (Figure 2). The pipe and blind rams were pressure tested to 600 psi.

A coring "sleeve" of 5 inch K-55, 15 lb/ft. casing with flush joint left hand buttress threads was run to TD and hung from the wellhead. On January 6 at 7 AM, core drilling using 101mm tools (3.98 inch hole with 2.50 inch core) commenced. The hole reached a depth of 1,007 feet at 10 AM on January 13 (7 days and 3 hours). The core barrel was retrieved and a deviation survey was run with a Spery-Sun single-shot camera suspended 18 feet below the bit. The camera assembly was hung from a bushing resting on the landing ring of the core bit. This arrangement prevents the assembly from going below the bit in case of cable failure. Survey stations were at 120 foot intervals. Deviation was less than one degree from vertical in a southerly direction (Table 2).

The 101mm drill rods were laid down in singles and 134mm drill rods were picked up for the rotary portion of the hole. The hole was back filled with cinder, bagasse (sugar cane waste), cotton seed hulls and multiseal. The material was washed down the open ended drill rods with a small flow of bentonite mud. Total material required to fill the hole: 6 cubic yards of bagasse; 1 cubic yard of cinder; 750 pounds of multiseal; and 550 pounds of cottonseed hulls. It was intended that the LCM together with cuttings would help seal permeable zones during the hole opening procedure. This technique had proved successful in the top section of the hole.

The drilling contractor had reservations about the ability of the U-5000 drill rig to open the hole to 12-1/4 inches in a single pass. Hole opening, therefore, was accomplished in two passes, using a 8-1/2 inch hole opener with a 3-15/16 inch pilot bit, followed with a 12-1/4 inch hole opener with a 8-1/2 inch pilot bit. Loss of circulation occured every few feet and numerous attempts were made to regain circulation by spotting LCM pills or dumping cinder, bagasse, paper sacks, bagged bentonite, etc. down the open hole. When fluid loss occured it was often immediate and total, bringing suspended cuttings down on the back side of the bit. Regaining circulation proved to be both expensive and temporary.

Small volume cement plugs were used in an attempt to seal problem intervals as the drilling progressed. Cement was batched in on-site grout mixing equipment (10 bbl and 20 bbl capacities) and either pumped down open ended drill rods or batched and poured down the open hole. Both efforts had early successes with decreasing results as the hole was deepened. Variations of these efforts continued from January 14 to February 7 (21 days) and the 12-1/4 inch hole was advanced from 107 - 579 feet.

During this period, two fishing jobs occured. The first was on January 22 when an inexperienced rig hand dropped a 16 inch cresent wrench down the hole. The wrench was milled up and drilling resumed after 21.5 hours. On January 24, three cones and shanks were lost in the hole when a 8-1/2 inch hole opener failed at 374 feet. Each piece was about 6 inches long and fishing efforts were complicated as the junk moved down the 4 inch core hole (filled with bagasse, cuttings and cinder) and wedged, destroying various junk baskets, a 134mm bit and SHR casing shoe. The 134mm bit and SHR casing shoe were used in attempts to core over the junk. The SHR attempt involved coring a 7 inch hole around the existing 4 inch hole. While it failed to retrieve any steel, it did result in a large enough diameter hole for the junk to lay flat and loose in the hole. This permitted most of the junk to be retrieved with a small magnet on January 28.

Following the failure of the 8-1/2 inch hole opener, the drill plan was modified and opening was completed to 12-1/4 inches in a single pass using a rotary bit and near-bit blade stabalizer. Rather than attempting to cure circulation problems as they occured, the hole was advanced in stages of approximately 200 feet without returns. During this period, the hole was often dry to bottom. The newly drilled interval was then backfilled with low strength redimix concrete (2.5 sacks per yard w/ 3/8 inch minus gravel).

and drilled out. On February 4, a Hughes ATJ-33 12-1/4 inch bit arrived and was used to open the hole from 579 - 992 feet. When pulled, the bit was still in good shape and was used on the next hole. Opening the hole in a single pass and cementing back larger segments of hole substantially increased progress on the hole (Figure 10) and hole opening advanced to 992 feet in 10 days.

9-5/8 inch, K-55 40 lb/ft BT&C casing was run to 990 feet with a guide shoe and float collar. Centralizers were run at every third joint, intervals of approximately 120 feet. The casing was cemented by Halliburton Services. Cement returns to the surface were not achieved on the first attempt and cementing was completed with 4 top jobs. The third top job brought cement to the surface prior to slowly draining away.

9-5/8 Inch Casing Cementing

Cmt. thru casing:	332 f.f. w/ 40% SiO2 & .65% CFR-3
First top job:	40 c.f. w/ 40% SiO2, .65% CFR-3 & 2% CaCl
Second top job:	81 c.f. w/ 40% SiO2, .65% CFR-3 & 2% CaCl
Third top job:	40 c.f. w/ 40% SiO2, .65% CFR-3 & 2% CaCl
Fourth top job:	29 sks. cmt. w/ 40% SiO2, 1,450# perlite, 5% CFR-3, 4% gel and 3% CaCl

A ring was installed between the 9-5/8 inch and 13-3/8 inch casings and the 13-5/8 inch BOP equipment described above was nippled up. A 8-1/2 inch bit was run in the hole and tagged cement at 937 feet. Cement and float equipment was drilled out to 992 feet and the rotary tools tripped out and laid down. A coring "sleeve" of 5 inch K-55 left hand threaded casing was run and hung from the wellhead and core drilling commenced with a 101mm (3.98 inch hole with 2.50 inch core) drilling assembly. Core drilling advanced to 2,000 feet in 11 days, averaging 91 feet per day.

The 101mm drill rods were tripped out and a deviation survey was run, with survey stations at 120 foot intervals, using a Sperry-Sun single shot tool suspended 18 feet below the bit. Deviation in the 1,000 - 2,000 foot interval is less than one degree from vertical in a southerly direction.

After the 5 inch casing sleeve was removed, the 134mm drill rods were picked up and a 8-1/2 inch drilling assembly consisting of a Hughes ATJ-33 bit and near bit blade stabalizer made up. Hole opening proceeded without returns and the hole was cemented back to the casing at 1,130 feet with 54 sacks of neat cement. Cement was tagged at 990 feet, reaming advanced to 1,390 feet with returns decreasing from 100 percent at 1,130 to 60 percent at 1,390 feet. The hole was cemented back with a 121 sack mix of neat cement. Cement was drilled out and the hole opened to 2,000 feet with 80 - 90 percent returns. After conditioning the hole, the drill rods were tripped out and 7 inch L-80, 35 lb/ft BT&C

casing with a guide shoe and float collar was run. Centralizers were set at every third joint, intervals of approximately 120 feet.

Cementing was delayed for 26 hours as a result of problems in shipping the Halliburton pump truck back to Hawaii from Oahu, where it had been sent on another job.

Circulation through the casing was achieved after building a pump pressure of 2,800 psi to break through an obstruction at the bottom of the casing string. Approximately 90 percent return of circulating fluids was maintained prior to cementing. Cementing was accomplished by pumping through the casing with returns to surface, which then slowly drained away. Cementing was completed with a single top job.

7 Inch Casing Cementing

34 bbls of clear water pumped ahead of lead slurry.

Lead slurry:	225 c.f. (75 sks. cmt., 2,850 # SiO2, 3,750 # spherelite, 95 # CFR-3 & 75 sks. bentonite)
Tail slurry:	126 c.f. (78 sks. cmt., 1,900 # SiO2, 37 # CFR-3 & 3 sks. CaCl)

Lead & tail slurry total 125% of theoretical.

Top job #1:	40 c.f. neat cement w/ 2% CaCl.

After waiting 12 hours on cement, a BOP assembly was nippled-up consisting of: 6 inch drilling valve, 7 inch LWS double-gate BOP, 6 inch Regan and rotating head (Figure 3). Seven inch casing was utilized to permit the running of an additional string of casing if down hole conditions warranted, and yet permit core drilling with HQ euipment. In order to core drill out of the 7 inch casing, a temporary "sleeve" of 4-1/2 inch casing was run to TD with a packer at the top of the first joint (approx. 40 feet off bottom) and centralizers on every third coupling. The purpose of the sleeve is to minimize lateral movement of the core drilling rods during rotation.

The hole was advanced to 5,290 feet with HQ coring equipment (3.82 inch hole with 2.50 inch core) from March 16 to April 25, a total of 41 days. Average daily footage was 80.5 feet. Several sandy, unstable intervals were encountered between 5,000 and 5,200 feet which required a number of redrills. At 5,290 feet the rods suddenly stuck, probably as a result of the sandy intervals below 5,000 feet caving in around the drill rods. Attempts by the driller to free the rods continued for 12 hours without success. The decision was made to reduce to NQ core. A steel ring was fabricated and welded on the HQ drill rods at the top of the wellhead to prevent cuttings from building up in the annular space between the HQ rods and 4-1/2 inch casing and the HQ rods were cut off below the drilling valve. An NQ coring assembly (2.98 inch hole with 1.875 inch core) was made up and drilling resumed on April 27. The hole was advanced to 6,562 feet on May 16, 1990. With NQ coring, daily footage averaged 67 feet from 5,290 feet to TD at 6,562 feet.

Below 5,692 feet, problems with rod "vibration" resulted from thermal break down of the polymer drilling fluids to the point where lubrication between the drilling rods and bore hole was no longer adequate to permit rotation. The subsequent vibration caused by excessive drag on the drill rods forced a reduction in drill rod rotation speed from 200 - 300 RPM to less than 100 RPM. At this depth bottom hole mud temperatures were approaching 450 F (Figure 9). High temperature polymer alone did not reduce the vibration problem. A combination of high temperature polymer and a torque reducing agent (brand name TORKease) reduced torque to normal levels and drilling continued.

Except for temporary rod vibration problems, core drilling progressed without incident to a depth of 6,562 feet where drilling operations were suspended. Although the permitted depth of the hole was between 4,000 feet and 6,500 feet, permission was obtained from the Hawaii Department of Land and Natural Resources ("DLNR") to deepen the hole. This was to accommodate any fill which might settle in the hole during completion activities.

The NQ drill rods were tripped out and stood in 40 foot stands. Open hole logs (induction, SP and gamma) were run below the HQ rods, which were set to 5,290 feet. The logging was contracted to Hot Hole Instruments, Inc. of Los Alamos, New Mexico.

An attempt to recover the HQ drill rods was then made. During the NQ drilling the rods had settled approximately 12 feet into the hole. They were recovered with a tap and pulled free with a 60,000 pound pull. The HQ rods separated at a connection 760 feet above the bit and 4,530 feet of HQ rods were recovered leaving 750 feet of HQ rods, a core barrel and bit in the hole. The 4-1/2 inch sleeve was removed and NQ drill rods were tripped in to check the hole condition prior to laying down the NQ rods in singles.

Slotted tubing, consisting of used NQ drill rods (2.75 inch OD x 2.376 inch ID) capped on bottom and perforated with 1/2 inch diameter holes drilled on 6 inch centers, was run to TD and hung from the wellhead. The completed wellhead assembly is shown in Figure 4. The completed well schematic is shown in Figure 1.

Injection testing, temperature and pressure logging was supervised by Geothermex Inc. and continued for several days following completion. Hot Hole Instruments, Inc. ran four temperature profiles and a spinner survey in the completed hole. W.T. Howard (GeothermEx) and John Deymonaz (SOH drilling manager) ran four temperature/pressure surveys during and following injection testing.

Drilling equipment was rigged down and operations at SOH-4 were terminated on May 25, 1990, the 151st day of operations.

Coring Footage

Figure 12 and Table 4 detail footages per shift (two 12 hour shifts per day). As would be expected, average footage declined slightly with increasing depth from over 50 feet per shift in the upper portions of the hole to about 35 feet per shift below 5,000 feet. This decrease resulted primarily from the length of time required to recover core and resume drilling (nearly one hour at depths below 5,000 feet). Intermittent drill rod vibration problems caused by thermal breakdown of drilling fluids forced a reduction in rotation speed which also lowered overall penetration rates. Rock competency never reached a point where the 10 foot core barrel could be replaced with a 20 foot barrel, which would reduce the number or core runs. The 20 foot barrel tends to vibrate more than a shorter barrel and unless the rock is extremely competent, the length of runs will actually be reduced by utilizing a longer core barrel.

Core Recovery

Average core recovery ranged from 85 - 100 percent (Figure 11 and Table 4). Shift recoveries of less than 30 percent are aberrations resulting from shifts with very limited footage during which core dropped from a tube during recovery or one poor run skewed the short footages for the shift. Figure 11, which plots shift core recovery vs. hole depth, graphically reflects the improving drilling conditions below 2,000 feet. Below 2,500 feet core recovery averages nearly 100 percent. The sharp downward spikes below 5,000 feet reflect unusual occurances on shifts with low footages (ie. 6 feet cored and 5 feet dropped from the barrel at 5,648 feet resulting in a 17 percent shift recovery) and not difficult drilling conditions. Unfortunately the good core recovery appears to correlate with the lack of formation permeability, which is very low below 2,500 feet.

Core Bit Footages

Core bits and rotary equipment experienced similar problems with the fractured basaltic rock. While the rock was medium in hardness and drilled relatively easily, it was extremely abrasive. This resulted in rapid loss of gauge on rotary bits without extensive gauge protection and rapid deterioration of matrix material and loss of inner and outer gauge on the core bits. As can be seen in Figure 13 and Table 5, core bit life increases substantially below 2,000 feet as the formations become softer, less abrasive and more competent due to alteration and secondary mineralization recementing fractured rock. While core bit life averaged less than 100 feet above 2,000 feet, this rapidly extended to 500 - 700 feet at greater depths.

Ground Water Sampling

Given the 1,195 foot surface elevation at SOH-4, ground water was anticipated at 1,000 - 1,200 feet. The hole was bailed at 1,135 feet for 4 hours with no improvement in water quality over the course of bailing. The sample appeared identical to the bentonite drilling fluid used in drilling. If a dynamic aquifer system exists at this depth, the fluid sample should have become less contaminated with drilling fluid as the hole was bailed and/or as time passed and the drilling fluids were carried away by the natural ground water movement. For example, at SOH-1 the fluids became markedly less contaminated during the sampling procedure.

Although core samples indicate numerous fractures and rubble zones in the upper 2,000 feet, the fluid sampling and the erratic nature of the fluid level in the hole while drilling suggest little lateral permeability. This may be a result of magmatic intrusions forming vertical impermeable zones in a box like structure. Such structures would create hydrologic cells with limited lateral fluid movement. When drilling fluids are introduced into this type of structure they collect around the bore hole rather than being carried "downstream" with the prevailing groundwater flow. Bailing simply retrieves much of the same fluid, which apparently occured in SOH-4.

Drill Hole Fluid Level

Beginning at a depth of 2,122 feet, fluid level in the hole was measured each time the overshot was run in the hole to retrieve the core barrel (Table 2 and Figure 14). Depending on the depth to the fluid level, this would occur 3 - 10 minutes after the mud pumps were cut off. When temperature measurements were taken the interval between cutting off the pumps and contacting the fluid level could be in excess of 15 minutes. Measurements recorded on temperature runs are marked with a "T". These are generally at a greater depth than the normal runs and indicate a slow decline in the fluid level after pumping ceased. By contrast, fluid level measurements in SOH-1 are consistently at 620 feet (approximately sea level).

From 2,122 - 2,271 feet, fluid levels ranged from 300 to 700 feet. Below 2,271 feet fluid levels dropped to a maximum of 1,100 feet and slowly rose to 350 feet. The shallower readings were made when the hole depth was below 5,800 feet and partial returns of drilling fluids to the surface were being observed while the pumps were engaged. The rise in fluid level was most likely due to the sealing of small fractures below the 2,000 foot casing depth by drill cuttings and the lack of significant permeable intervals below 2,500 feet.

Bottom Hole Temperature Measurements

Maximum reading mercury filled thermometers ("MRT's") were used to obtain bottom hole temperatures ("BHT's) beginning at a depth of 3,210 feet (Figure 9 and Table 3). The thermometers were placed in a sealed pressure vessel (1/4 inch steel pipe capped at both ends) which was run in a perforated cage and suspended approximately one foot below the drill bit for 10 minutes. This gave a reading close to bottom approximately one hour after circulation ceased and reflected drilling fluid temperatures near actual formation temperatures if drilling fluids were not migrating into nearby rock. Beginning at 5,280 feet, to minimize rig time, measurements were made by placing the thermometer vessel above the overshot while retrieving the core barrel and left on bottom for 5 minutes. This gave a reading 20 feet off bottom approximately 30 minutes after pumping ceased. Both methods appear to give similar results although the latter will tend to vary more from actual formation temperatures.

A comparison of the BHT's to a temperature profile run 18 hours after an injection test on June 22 reveals a good correlation to temperature trends in the relatively equilibrated hole. Equilibrated temperatures vary from 50 to 122 degrees F higher than BHT's above 4,700 feet to 15 to 33 degree F higher than BHT's below 4,700 feet. The 4,700 foot interval appears to be a somewhat permeable zone below which no significant permeability is indicated. As is common in core drilled holes, the BHT's were excellent indicators of changes in formation temperature, and in intervals of low permeability correlate very closely with actual formation temperatures. This results from the low pump rate (10 - 15 gallons per minute) and small hole diameter which tends to have a minimal cooling effect on the surrounding rock.

Water Requirements

One of the advantages of core drilling non-producing test holes rather than drilling with rotary methods is the low fluid injection rate required while coring. This is a major advantage when drilling without returns in areas where securing an adequate water supply is difficult. Unfortunately, after the drilling contractor and equipment were selected for this project, the drilling program was modified to include larger and deeper strings of casing (Figure 1) requiring more extensive rotary drilling then originally planned for. Since the site was designed primarily for core drilling operations, and to minimize surface disturbance, a small (100 feet by 125 feet) site was cleared. Space for water storage was limited. Water storage consisted of 23,000 gallon and 3,500 gallon storage tanks and two grout tanks. On site storage totaled about 28,000 gallons.

Water for drilling was transported in from a Hawaii Conty water supply stand pipe located 5 miles from the drill site in 5,000 gallon tanker trucks. Water consumption while core drilling without returns was 10 - 15 gallons per minute and one truck could keep the rig supplied with sufficient water. Although 3 - 4 trucks could keep up with rotary drilling under the worst of conditions, Hawaii County regulations for this project prohibited all heavy truck traffic to the site from 7 AM to 7 PM. Standby periods for waiting on cement and drilling out cement, during which time full returns were obtained, was scheduled for night shifts when water hauling was not allowed.

Even with the scheduling of low water use operations for night time periods, 3 - 5 hours of standby occured on most nights while opening the 12-1/4 inch hole.

Figures 5, 6, 7 and 8 graph various aspects of water consumption with depth, time and cost. In Figure 5, the period from Day 40 to Day 51 illustrates the increase in water (ie. drilling fluid) consumption while opening with the 12-1/4 inch bit. Fluid consumption averaged 70,000 - 100,000 gallons per day. By contrast, core drilling during days 12 - 19 and 80 - 142 are reflected by a uniform fluid consumption of 15,000 to 20,000 gallons per day. The erratic nature of water consumption during rotary operations was due to periods of cementing, waiting on cement and drilling out cement with returns interspersed between periods of hole opening without returns.

Drilling Fluids

Environmental concerns are of primary importance in the SOH program. While modern drilling fluids are not considered to be a health hazzard by the U.S. Environmental Protection Agency, certain items in concentrated form must be handled with care. The drilling fluids selected for the SOH project are acceptable for drilling domestic water wells in many states. Prior to beginning the project, a representative from the state of Nevada Water Resources Division was asked to review the list of drilling fluids to be used on the SOH program as it would pretain to a domestic water well drilling program.

Since circulation was not expected during the coring portion of SOH-4, the drilling fluids were designed to be as inexpensive as possible and still maximize drilling performance. In the upper, cooler portions of the hole a bentonite based mud was used with 1.5 ounces of 35 percent polyacrilamide and 12 pounds of extra high yield bentonite per barrel of fluid. Below 5,000 feet, as bottom hole temperatures exceeded 400 F, high temperature polymer (in this case Nova Mud Company's Thermovis) together with high temperature lubricants, surfactants and corrosion control additives were incorporated into the mud system.

Drilling Costs

Total drilling costs for SOH-4 were $1,466,813. This is exclusive of transportation from Salt Lake City to Hilo and also does not include equipment modifications prior to arrival in Hilo. Table 6 presents a brief breakdown of the major costs by activity and item. Figure 17 is a graphic representation of drilling costs vs. hole depth.

Tables & Figures

Table 2

SOH-4
Deviation Measurements

Depth (ft)	Bearing	Degrees
200	S-05-W	0.50
400	S-16-E	0.75
600	S-34-W	0.25
800	S-38-W	0.50
1,014	S-13-W	0.50
1,094	S-09-W	0.25
1,194	S-03-W	0.50
1,294	S-04-W	0.50
1,344	S-24-E	0.50
1,494	S-36-W	0.25
1,594	S-34-W	0.50
1,694	S-04-W	0.75
1,794	S-13-E	0.50
1,894	S-11-W	0.75
1,994	S-17-W	0.50

Table 3
SOH-4
DRILLING COSTS AND ACTIVITIES

Activity	Date	Day #	Footage Start	Footage End	Daily Footage	Daily Cost	Cost-to Date
Mob, set-up, site const.	Dec 1 - 13					40,548	40,548
Finish rig, core 134mm	14-Dec	1	0	88	88	10,887	51,435
Core 134mm & open 8.5"	15-Dec	2	88	112	24	9,317	60,752
Open 8.5" & 12.25"	16-Dec	3	112	114	2	9,862	70,614
Open 12.25" & 17.5"	17-Dec	4	114	114	0	11,042	81,656
Open 17.5"	18-Dec	5	114	114	0	7,019	88,675
Open 17.5", attempt csg.	19-Dec	6	114	121	7	6,526	95,201
Ream hole	20-Dec	7	121	121	0	6,068	101,269
Ream hole, stop for X-mas	21-Dec	8	121	121	0	4,842	106,111
Run 13-3/8" csg	04-Jan	9	121	121	0	13,004	119,115
Cmt, WOC	05-Jan	10	121	121	0	6,923	126,038
Nipple up BOPE, test	06-Jan	11	121	121	0	6,657	132,695
Core 101mm	07-Jan	12	121	262	141	8,843	141,538
Core 101mm	08-Jan	13	262	422	160	11,702	153,240
Core 101mm	09-Jan	14	422	572	150	8,819	162,059
Core 101mm	10-Jan	15	572	686	114	10,309	172,368
Core 101mm	11-Jan	16	686	780	94	8,757	181,125
Core 101mm	12-Jan	17	780	898	118	7,711	188,836
Core 101mm	13-Jan	18	898	961	63	9,328	198,164
Core 101mm, dev survey	14-Jan	19	961	1,007	46	7,112	205,276
LCM hole, run sleeve	15-Jan	20	1007	1,007	0	9,336	214,612
Open 8.5", POH, LCM hole	16-Jan	21	1007	1,007	0	8,643	223,255
Open 12.25", POH	17-Jan	22	1007	1,007	0	9,446	232,701
Cmt, open 8.5"	18-Jan	23	1007	1,007	0	6,284	238,985
Cmt, open 8.5" & 12.25"	19-Jan	24	1007	1,007	0	6,462	245,447
Open 8.5" & cmt	20-Jan	25	1007	1,007	0	9,589	255,036
Cmt, WOC, open 12.25"	21-Jan	26	1007	1,007	0	7,146	262,182
Open 12.25" & cmt.	22-Jan	27	1007	1,007	0	6,199	268,381
WOC, open 12.25" & fish	23-Jan	28	1007	1,007	0	7,416	275,797
Fish & open 8.5"	24-Jan	29	1007	1,007	0	5,184	280,981
Open 8.5", fish for H/O	25-Jan	30	1007	1,007	0	10,789	291,770
Fish	26-Jan	31	1007	1,007	0	7,386	299,156
Fish & cmt.	27-Jan	32	1007	1,007	0	6,364	305,520
Open 12.25" & cmt.	28-Jan	33	1007	1,007	0	7,526	313,046
Open 12.25" & fish	29-Jan	34	1007	1,007	0	12,294	325,340
Open 12.25" & 8.5" & cmt.	30-Jan	35	1007	1,007	0	9,115	334,455
WOC, open 12.25"	31-Jan	36	1007	1,007	0	10,405	344,860
Cmt., WOC, open 12.25"	01-Feb	37	1007	1,007	0	7,159	352,019
Cmt, open 12.25"	02-Feb	38	1007	1,007	0	8,175	360,194
Open 12.25"	03-Feb	39	1007	1,007	0	9,063	369,257
Open 12.25", cmt & WOC	04-Feb	40	1007	1,007	0	7,844	377,101
Open 12.25"	05-Feb	41	1007	1,007	0	15,487	392,588
Open 12.25	06-Feb	42	1007	1,007	0	9,704	402,292
Open 12.25", cmt & WOC	07-Feb	43	1007	1,007	0	9,799	412,091
LCM hole, drl cmt.	08-Feb	44	1007	1,007	0	10,718	422,809
Open 12.25"	09-Feb	45	1007	1,007	0	9,484	432,293

SITE CONSTRUCTION, MOB & SETUP & SET-UP
Total Cost $42,297

CORE 101mm (0 - 112 ft)
112 ft. @ $13,703
Cost/foot $122.35

OPEN 17-1/2" HOLE (0 - 112 ft)
112 ft. @ $53,847
Cost/foot $480.78

CASING OPERATIONS (13-3/8" csg 0 - 112 ft)
Total Cost $31,886
Cost/foot $284.70

CORE 101mm (112 - 1,008 ft)
896 ft. @ $65,930
Cost/foot $73.58

Table 3
SOH-4
DRILLING COSTS AND ACTIVITIES

Activity	Date	Day #	Footage Start	Footage End	Daily Footage	Daily Cost	Cost-to Date			
Open 12.25", cmt & WOC	10-Feb	46	1007	1,007	0	10,074	442,367			
WOC & open 12.25"	11-Feb	47	1007	1,007	0	8,981	451,348	OPEN 12-1/4" HOLE		
Open 12.25"	12-Feb	48	1007	1,007	0	8,309	459,657	(112 - 992 ft)		
Open 12.25"	13-Feb	49	1007	1,007	0	9,296	468,953		880 ft. @	$283,609
Open 12.25 & cmt.	14-Feb	50	1007	1,007	0	8,985	477,938		Cost/foot	$322.28
Drl cmt, POH, remove BOPE	15-Feb	51	1007	1,007	0	8,673	486,611			
Run & cmt 9-5/8" csg.	16-Feb	52	1007	1,007	0	24,454	511,065	CASING OPERATIONS (9-5/8" csg		
Finish cmt casing.	17-Feb	53	1007	1,007	0	23,925	534,990	0 - 992 ft)		
Drl cmt, core 101mm	18-Feb	54	1007	1,032	25	9,038	544,028		Total Cost	$53,617
Core 101mm	19-Feb	55	1032	1,125	93	8,574	552,602		Cost/foot	$54.05
Core 101mm, bail sample	20-Feb	56	1125	1,191	66	7,605	560,207			
Core 101mm	21-Feb	57	1191	1,285	94	9,110	569,317			
Core 101mm	22-Feb	58	1285	1,380	95	8,213	577,530			
Core 101mm	23-Feb	59	1380	1,475	95	6,900	584,430			
Core 101mm	24-Feb	60	1475	1,563	88	8,738	593,168			
Core 101mm	25-Feb	61	1563	1,673	110	7,152	600,320			
Core 101mm	26-Feb	62	1673	1,769	96	8,058	608,378			
Core 101mm	27-Feb	63	1769	1,838	69	8,483	616,861	CORE 101mm (1,008 - 2,000 ft)		
Core 101mm & repairs	28-Feb	64	1838	1,920	82	6,869	623,730		992 ft. @	$89,452
Core 101mm & dev survey	01-Mar	65	1920	2,000	80	12,219	635,949		Cost/foot	$90.17
POH & open 8.5"	02-Mar	66	995	1,040	45	6,720	642,669			
Open 8.5" & cmt.	03-Mar	67	1040	1,130	90	8,232	650,901			
Cmt, WOC & drl cmt	04-Mar	68	1130	1,130	0	7,779	658,680			
Drl cmt & open 8.5"	05-Mar	69	1130	1,300	170	8,371	667,051			
Open 8.5" & cmt	06-Mar	70	1300	1,390	90	7,694	674,745			
Dr. cmt & open 8.5"	07-Mar	71	1390	1,490	100	7,319	682,064			
Open 8.5"	08-Mar	72	1490	1,680	190	7,284	689,348	OPEN 8-1/2" HOLE		
Open 8.5"	09-Mar	73	1680	1,850	170	6,586	695,934	(992 - 2,000 ft)		
Open 8.5"	10-Mar	74	1850	1,980	130	7,365	703,299		1,008 ft. @	$78,311
Open 8.5" & condition	11-Mar	75	1980	2,000	20	6,684	709,983		Cost/foot	$77.69
Wait on HOWCO	12-Mar	76	2000	2,000	0	6,238	716,221			
Run csg, wait on HOWCO	13-Mar	77	2000	2,000	0	40,236	756,457	CASING OPERATIONS (7" csg.		
Cmt csg & WOC	14-Mar	78	2000	2,000	0	18,257	774,714	0 - 2,000 ft)		
Nipple up BOPE & drl cmt.	15-Mar	79	2000	2,000	0	13,380	788,094		Total Cost	$82,249
POH, run sleeve & core HQ	16-Mar	80	2000	2,023	23	6,807	794,901		Cost/foot	$41.12
Core HQ	17-Mar	81	2023	2,112	89	6,643	801,544			
Core HQ	18-Mar	82	2112	2,220	108	8,204	809,748			
Core HQ	19-Mar	83	2220	2,281	61	6,169	815,917			
Core HQ	20-Mar	84	2281	2,392	111	8,554	824,471			
Core HQ	21-Mar	85	2392	2,502	110	9,090	833,561			
Core HQ	22-Mar	86	2502	2,611	109	8,013	841,574			
Core HQ	23-Mar	87	2611	2,680	69	6,849	848,423			
Core HQ	24-Mar	88	2680	2,784	104	7,349	855,772			
Core HQ	25-Mar	89	2784	2,894	110	8,251	864,023			
Core HQ	26-Mar	90	2894	3,003	109	7,839	871,862			
Core HQ	27-Mar	91	3003	3,100	97	7,613	879,475			

Table 3
SDH-4
DRILLING COSTS AND ACTIVITIES

Activity	Date	Day #	Footage Start	Footage End	Daily Footage	Daily Cost	Cost-to Date	
Core HQ	28-Mar	92	3100	3,160	60	8,479	887,954	
Core HQ	29-Mar	93	3160	3,268	108	8,385	896,339	
Core HQ	30-Mar	94	3268	3,365	97	8,121	904,460	
Core HQ	31-Mar	95	3365	3,462	97	8,509	912,969	
Core HQ	01-Apr	96	3462	3,510	48	12,339	925,308	
Core HQ	02-Apr	97	3510	3,610	100	7,749	933,057	
Core HQ	03-Apr	98	3610	3,706	96	7,837	940,894	
Core HQ	04-Apr	99	3706	3,796	90	7,449	948,343	
Core HQ	05-Apr	100	3796	3,885	89	7,361	955,704	
Core HQ	06-Apr	101	3885	3,962	77	7,037	962,741	
Core HQ	07-Apr	102	3962	4,052	90	8,303	971,044	
Core HQ	08-Apr	103	4052	4,090	38	6,622	977,666	
Core HQ	09-Apr	104	4090	4,170	80	8,233	985,899	
Core HQ	10-Apr	105	4170	4,258	88	8,539	994,438	
Core HQ	11-Apr	106	4258	4,347	89	8,352	1,002,790	
Core HQ	12-Apr	107	4347	4,435	88	8,119	1,010,909	
Core HQ	13-Apr	108	4435	4,524	89	8,423	1,019,332	
Core HQ	14-Apr	109	4524	4,613	89	7,992	1,027,324	
Core HQ	15-Apr	110	4613	4,701	88	8,169	1,035,493	
Core HQ	16-Apr	111	4701	4,743	42	7,323	1,042,816	
Core HQ	17-Apr	112	4743	4,811	68	7,299	1,050,115	
Core HQ	18-Apr	113	4811	4,890	79	8,573	1,058,688	
Core HQ	19-Apr	114	4890	4,935	45	7,180	1,065,868	
Core HQ	20-Apr	115	4935	5,018	83	8,656	1,074,524	
Core HQ	21-Apr	116	5018	5,073	55	7,546	1,082,070	
Core HQ	22-Apr	117	5073	5,098	25	7,473	1,089,543	
Core HQ	23-Apr	118	5098	5,152	54	8,245	1,097,788	CORE HQ (2,000 - 5,290 ft)
Core HQ	24-Apr	119	5152	5,211	59	7,798	1,105,586	3,290 ft. @ $326,956
Core HQ	25-Apr	120	5211	5,290	79	10,086	1,115,672	Cost/foot $99.38
Stick rods & run NQ	26-Apr	121	5290	5,290	0	6,185	1,121,857	
Prepare for NQ coring	27-Apr	122	5290	5,290	0	6,298	1,128,155	
Core NQ	28-Apr	123	5290	5,332	42	7,542	1,135,697	
Core NQ	29-Apr	124	5332	5,402	70	9,081	1,144,778	
Core NQ	30-Apr	125	5402	5,482	80	9,434	1,154,212	
Core NQ	01-May	126	5482	5,562	80	8,931	1,163,143	
Core NQ	02-May	127	5562	5,642	80	9,394	1,172,537	
Core NQ	03-May	128	5642	5,672	30	7,653	1,180,190	
Core NQ	04-May	129	5672	5,752	80	9,415	1,189,605	
Core NQ	05-May	130	5752	5,822	70	8,774	1,198,379	
Core NQ	06-May	131	5822	5,912	90	9,744	1,208,123	
Core NQ	07-May	132	5912	5,979	67	8,717	1,216,840	
Core NQ	08-May	133	5979	6,039	60	8,950	1,225,790	
Core NQ	09-May	134	6039	6,113	74	10,136	1,235,926	
Core NQ	10-May	135	6113	6,158	45	7,841	1,243,767	
Core NQ	11-May	136	6158	6,222	64	9,412	1,253,179	
Core NQ	12-May	137	6222	6,296	74	9,752	1,262,931	

Table 3
SDH-4
DRILLING COSTS AND ACTIVITIES

Activity	Date	Day #	Footage Start	Footage End	Daily Footage	Daily Cost	Cost-to Date		
Core NQ	13-May	138	6296	6,367	71	9,852	1,272,783		
Core NQ	14-May	139	6367	6,402	35	8,045	1,280,828	CORE NQ (5,290 - 6,562 ft)	
Core NQ	15-May	140	6402	6,469	67	9,660	1,290,488	1,272 ft. @	$205,311
Core NQ	16-May	141	6469	6,552	83	10,964	1,301,452	Cost/foot	$161.41
Core NQ, reach TD & POH	17-May	142	6552	6,562	10	6,678	1,308,130		
POH w/ NQ, HQ & 4.5" csg	18-May	143	6562	6,562	0	15,855	1,323,985		
RIH w/ NQ & lay down	19-May	144	6562	6,562	0	6,365	1,330,350		
Run tubing.	20-May	145	6562	6,562	0	38,406	1,368,756		
Run tubing & survey	21-May	146	6562	6,562	0	62,040	1,430,796		
Survey & injection test	22-May	147	6562	6,562	0	10,818	1,441,614		
Survey & injection test	23-May	148	6562	6,562	0	5,686	1,447,300		
Survey & injection test	24-May	149	6562	6,562	0	6,698	1,453,998	COMPLETION, LOGGING,	
Rig down	25-May	150	6562	6,562	0	4,570	1,458,568	TEST & RIGGING DOWN	
Rig down & move	26-May	151	6562	6,562	0	8,279	1,466,847	Total Cost	$139,680

TOTAL DRILLING COSTS $1,466,847

Table 4

SOH-4
101mm coring

Day	Shift	Driller	Start	End	Total	Recovered	Percent
12	D	ML	114.2	169.3	55.1	36.0	65%
12	N	JG	169.3	257.8	88.5	79.7	90%
13	D	ML	257.8	326.7	68.9	56.8	82%
13	N	JG	326.7	415.3	88.6	82.2	93%
14	D	ML	415.3	482.2	66.9	56.2	84%
14	N	JG	482.2	562.9	80.7	74.0	92%
15	D	ML	562.9	620.9	58.0	53.2	92%
15	N	JG	620.9	675.1	54.2	42.2	78%
16	D	ML	675.1	728.7	53.6	46.8	87%
16	N	JG	728.7	767.5	38.8	23.4	60%
17	D	ML	767.5	818.7	51.2	51.2	100%
17	N	JG	818.7	883.8	65.1	56.4	87%
18	D	ML	883.8	915.1	31.3	30.8	98%
18	N	JG	915.1	945.6	30.5	28.1	92%
19	D	ML	945.6	987.5	41.9	39.9	95%
19	N	JG	987.5	991.0	3.5	2.0	57%
54	N	BC	997.0	1,032.0	35.0	25.0	71%
55	D	JG	1,032.0	1,087.0	55.0	50.0	91%
55	N	BC	1,087.0	1,125.0	38.0	34.0	89%
56	D	JG	1,125.0	1,145.0	20.0	17.0	85%
56	N	BC	1,145.0	1,191.0	46.0	34.5	75%
57	D	JG	1,191.0	1,248.0	57.0	48.0	84%
57	N	BC	1,248.0	1,285.0	37.0	26.0	70%
58	D	JG	1,285.0	1,347.0	62.0	56.0	90%
58	N	BC	1,347.0	1,383.0	36.0	24.5	68%
59	D	JG	1,383.0	1,418.0	35.0	34.0	97%
59	N	BC	1,418.0	1,475.5	57.5	48.7	85%
60	D	JG	1,475.5	1,519.0	43.5	31.5	72%
60	N	BC	1,519.0	1,563.5	44.5	35.5	80%
61	D	JG	1,563.5	1,618.0	54.5	52.0	95%
61	N	BC	1,618.0	1,673.0	55.0	47.5	86%
62	D	JG	1,673.0	1,711.0	38.0	36.0	95%
62	N	BC	1,711.0	1,769.0	58.0	51.0	88%
63	D	JG	1,769.0	1,812.0	43.0	35.5	83%
63	N	BC	1,812.0	1,838.5	26.5	22.5	85%
64	D	ML	1,838.5	1,866.0	27.5	25.5	93%
64	N	BC	1,866.0	1,920.0	54.0	51.8	96%
65	D	ML	1,920.0	1,986.0	66.0	65.5	99%
65	N	BC	1,986.0	2,000.0	14.0	13.0	93%
	Overall averages				1,879.8	1,623.9	86%
	ML 10 shift		52.0 ft/shift		520.4	461.9	89%
	JG 16 shifts		53.4 ft/shift		854.4	746.0	87%
	BC 11 shifts		44.3 ft/shift		487.5	401.0	82%

SOH-4
101mm core

Day	Shift	Run	Depth From	Depth To	Footage Cored	Footage Recovered	Percent Recovery
12	D	1	114.2	120.1	5.9	4.0	68%
Mike		2	120.1	129.9	9.8	7.0	71%
55.1 ft. tot		3	129.9	139.8	9.9	7.0	71%
36.0 ft. recov		4	139.8	149.6	9.8	6.0	61%
65%		5	149.6	159.4	9.8	5.0	51%
		6	159.4	169.3	9.9	7.0	71%
12	N	1	169.3	179.1	9.8	9.8	100%
Jerry		2	179.1	189.0	9.9	9.0	91%
88.5 ft. tot		3	189.0	198.8	9.8	9.5	97%
79.7 ft. recov		4	198.8	208.6	9.8	9.8	100%
90%		5	208.6	218.5	9.9	7.0	71%
		6	218.5	228.3	9.8	6.0	61%
		7	228.3	238.2	9.9	9.8	99%
		8	238.2	248.0	9.8	9.8	100%
		9	248.0	257.8	9.8	9.0	92%
13	D	1	257.8	267.7	9.9	9.0	91%
Mike		2	267.7	277.5	9.8	6.0	61%
68.9 ft. tot		Trip for bit					
56.8 ft. recov		3	277.5	287.4	9.9	9.8	99%
82%		4	287.4	295.2	7.8	6.0	77%
		5	295.2	304.2	9.0	7.0	78%
		Broke overshot, trip out					
		6	304.2	310.0	5.8	4.0	69%
		7	310.0	316.9	6.9	6.0	87%
		8	316.9	326.7	9.8	9.0	92%
13	N	1	326.7	336.6	9.9	9.8	99%
Jerry		Broke overshot, trip out					
88.6 ft. tot		2	336.6	340.6	4.0	3.0	75%
82.2 ft. recov		3	340.6	344.4	3.8	3.8	100%
93%		4	344.4	356.2	11.8	9.8	83%
		5	356.2	366.1	9.9	8.5	86%
		6	366.1	375.9	9.8	9.8	100%
		7	375.9	385.8	9.9	9.8	99%
		8	385.8	395.6	9.8	8.0	82%
		9	395.6	405.4	9.8	9.8	100%
		10	405.4	411.4	6.0	6.0	100%
		11	411.4	415.3	3.9	3.9	100%
14	D	1	415.3	425.1	9.8	5.0	51%
Mike		2	425.1	427.1	2.0	0.5	25%
66.9 ft. tot		Trip for bit					
56.2 ft. recov		3	427.1	430.1	3.0	2.0	66%
84%		4	430.1	435.0	4.9	4.9	100%
		Sand in tube, trip					
		5	435.0	444.8	9.8	8.0	82%
		6	444.8	452.6	7.8	7.8	100%

SOH-4
101mm core

Day	Shift	Run	Depth From	Depth To	Footage Cored	Footage Recovered	Percent Recovery
		7	452.6	463.5	10.9	10.2	94%
		8	463.5	472.3	8.8	8.0	91%
		9	472.3	482.2	9.9	9.8	99%
14	N	1	482.2	490.7	8.5	8.5	100%
Jerry		2	490.7	496.0	5.3	4.0	75%
80.7 ft. tot		3	496.0	503.8	7.8	7.0	90%
74.0 ft. recov		4	503.8	505.8	2.0	0.0	0%
92%		Sand in tube, trip					
		5	505.8	513.7	7.9	7.0	89%
		6	513.7	523.5	9.8	9.8	100%
		7	523.5	533.4	9.9	9.0	91%
		8	533.4	542.2	8.8	8.0	91%
		9	542.2	549.2	7.0	7.0	100%
		10	549.2	559.0	9.8	9.8	100%
		11	559.0	562.9	3.9	3.9	100%
15	D	Trip for bit					
Mike		1	562.9	566.9	4.0	3.0	75%
58.0 ft. tot		2	566.9	572.7	5.8	5.0	86%
53.2 ft. recov		3	572.7	582.6	9.9	9.8	99%
92%		4	582.6	592.4	9.8	9.8	100%
		5	592.4	602.2	9.8	9.8	100%
		6	602.2	612.1	9.9	9.8	99%
		7	612.1	620.9	8.8	6.0	68%
		Trip for bit, ream & wash to bottom from 430 ft.					
15	N	1	620.9	631.3	10.4	10.4	100%
Jerry		2	631.3	636.8	5.5	3.0	55%
54.2 ft. tot		3	636.8	641.6	4.8	4.8	100%
42.2 ft. recov		4	641.6	649.1	7.5	6.0	80%
78%		5	649.1	654.4	5.3	4.0	75%
		6	654.4	656.4	2.0	0.0	0%
		Trip for bit, ream & wash at 300 ft & 430 ft. 10 ft fill on b					
		7	656.4	660.8	4.4	3.0	68%
		Stuck tube, trip					
		8	660.8	669.1	8.3	7.0	84%
		9	669.1	675.1	6.0	4.0	67%
16	D	1	675.1	683.0	7.9	7.0	89%
Mike		2	683.0	689.3	6.3	6.0	95%
53.6 ft. tot		3	689.3	693.8	4.5	4.0	89%
46.8 ft. recov		4	693.8	698.6	4.8	4.5	94%
87%		5	698.6	704.6	6.0	6.0	100%
		6	704.6	708.1	3.5	3.5	100%
		7	708.1	711.5	3.4	3.0	88%
		8	711.5	716.5	5.0	5.0	100%
		9	716.5	721.3	4.8	4.8	100%
		10	721.3	724.8	3.5	2.0	57%

SOH-4
101mm core

Day	Shift	Run	Depth From	Depth To	Footage Cored	Footage Recovered	Percent Recovery
		11	724.8	728.7	3.9	1.0	26%
16	N	1	728.7	738.0	9.3	3.0	32%
Jerry		2	738.0	745.0	7.0	0.0	0%
38.8 ft. tot		Pull up 20 & redrill					
23.4 ft. recov		3	745	745.5	0.5	0.0	0%
60%		Trip for bit					
		4	745.5	749.3	3.8	3.0	79%
		5	749.3	757.7	8.4	8.4	100%
		6	757.7	767.5	9.8	9.0	92%
17	D	1	767.5	771.0	3.5	3.5	100%
Mike		2	771.0	773.5	2.5	2.5	100%
51.2 ft. tot		3	773.5	779.4	5.9	5.9	100%
51.2 ft. recov		4	779.4	789.2	9.8	9.8	100%
100%		5	789.2	799.0	9.8	9.8	100%
		6	799.0	808.9	9.9	9.9	100%
		7	808.9	818.7	9.8	9.8	100%
17	N	1	818.7	828.6	9.9	9.9	100%
Jerry		2	828.6	838.4	9.8	9.8	100%
65.1 ft. tot		3	838.4	848.2	9.8	9.8	100%
56.4 ft. recov		4	848.2	852.7	4.5	3.0	67%
87%		5	852.7	859.0	6.3	3.0	48%
		6	859.0	867.9	8.9	7.0	79%
		7	867.9	872.9	5.0	3.0	60%
		8	872.9	877.8	4.9	4.9	100%
		9	877.8	883.8	6.0	6.0	100%
18	D	1	883.8	894.1	10.3	10.3	100%
Mike		2	894.1	901.4	7.3	7.3	100%
31.3 ft. tot		3	901.4	907.3	5.9	5.9	100%
30.8 ft. recov		4	907.3	910.3	3.0	2.5	83%
98%		Trip for bit & ream back to bottom					
		5	910.3	915.1	4.8	4.8	100%
18	N	1	915.1	926.5	11.4	10.5	92%
Jerry		2	926.5	933.0	6.5	5.0	77%
30.5 ft. tot		3	933.0	935.3	2.3	2.3	100%
28.1 ft. recov		4	935.3	939.8	4.5	4.5	100%
92%		5	939.8	940.3	0.5	0.5	100%
		Trip for bit & wash to bottom					
		6	940.3	945.6	5.3	5.3	100%
19	D	1	945.6	952.6	7.0	7.0	100%
Mike		2	952.6	959.5	6.9	6.9	100%
41.9 ft. tot		3	959.5	965.3	5.8	5.8	100%
39.9 ft. recov		4	965.3	970.3	5.0	5.0	100%
95%		5	970.3	974.2	3.9	3.9	100%

SOH-4
101mm core

Day	Shift	Run	Depth From	Depth To	Footage Cored	Footage Recovered	Percent Recovery
		6	974.2	976.7	2.5	2.0	80%
		7	976.7	980.2	3.5	3.0	86%
		8	980.2	984.5	4.3	4.3	100%
		9	984.5	987.5	3.0	2.0	67%
19	N	1	987.5	991.0	3.5	2.0	57%
Jerry							
3.5 ft. tot							
2.0 ft. recov		Total for interval			876.8	758.9	87%
57%							
54	N	1	997.0	1,003.0	6.0	5.0	83%
Bill		2	1,003.0	1,015.0	12.0	10.0	83%
35.0 ft. tot		3	1,015.0	1,023.0	8.0	4.0	50%
25.0 ft. recov		4	1,023.0	1,032.0	9.0	6.0	67%
71%							
55	D	1	1,032.0	1,037.0	5.0	3.0	60%
		2	1,037.0	1,042.0	5.0	3.0	60%
Jerry		3	1,042.0	1,052.0	10.0	9.0	90%
55.0 ft. tot		4	1,052.0	1,062.0	10.0	10.0	100%
50.0 ft. recov		5	1,062.0	1,066.5	4.5	4.5	100%
91%		6	1,066.5	1,072.0	5.5	5.5	100%
		Bail hole for water sample					
		7	1,072.0	1,078.0	6.0	6.0	100%
		Rig repairs					
		8	1,078.0	1,087.0	9.0	9.0	100%
55	N	1	1,087.0	1,093.0	6.0	2.0	33%
Bill		2	1,093.0	1,098.5	5.5	5.5	100%
38.0 ft. tot		3	1,098.5	1,109.0	10.5	10.5	100%
34.0 ft. recov		4	1,109.0	1,119.0	10.0	10.0	100%
89%		5	1,119.0	1,125.0	6.0	6.0	100%
56	D	1	1,125.0	1,130.0	5.0	5.0	100%
		2	1,130.0	1,133.0	3.0	3.0	100%
Jerry		3	1,133.0	1,135.0	2.0	2.0	100%
20.0 ft. tot		Rig repairs, bail hole for water sample					
17.0 ft. recov		4	1,135.0	1,141.0	6.0	3.0	50%
85%		5	1,141.0	1,145.0	4.0	4.0	100%
56	N	1	1,145.0	1,152.0	7.0	5.0	71%
		2	1,152.0	1,160.0	8.0	7.5	94%
Bill		3	1,160.0	1,164.0	4.0	3.0	75%
46.0 ft. tot		4	1,164.0	1,168.5	4.5	2.0	44%
34.5 ft. recov		5	1,168.5	1,173.0	4.5	3.0	67%
75%		6	1,173.0	1,178.0	5.0	4.5	90%

SOH-4
101mm core

Day	Shift	Run	Depth From	Depth To	Footage Cored	Footage Recovered	Percent Recovery
		7	1,178.0	1,184.0	6.0	4.0	67%
		8	1,184.0	1,191.0	7.0	5.5	79%
57	D	1	1,191.0	1,200.0	9.0	6.0	67%
		2	1,200.0	1,210.0	10.0	9.0	90%
Jerry		3	1,210.0	1,216.0	6.0	6.0	100%
57.0 ft. tot		4	1,216.0	1,222.0	6.0	6.0	100%
48.0 ft. recov		5	1,222.0	1,232.0	10.0	6.0	60%
84%		6	1,232.0	1,241.0	9.0	8.0	89%
		7	1,241.0	1,248.0	7.0	7.0	100%
57	N	1	1,248.0	1,254.5	6.5	4.0	62%
		2	1,254.5	1,260.5	6.0	4.5	75%
Bill		3	1,260.5	1,266.5	6.0	4.0	67%
37.0 ft. tot		Trip for bit					
26.0 ft. recov		Ream in 55 ft, 3.5 ft fill					
70%		4	1,266.5	1,267.0	0.5	0.5	100%
		5	1,267.0	1,272.5	5.5	4.5	82%
		6	1,272.5	1,277.0	4.5	3.0	67%
		7	1,277.0	1,285.0	8.0	5.5	69%
58	D	1	1,285.0	1,292.0	7.0	7.0	100%
		2	1,292.0	1,302.0	10.0	8.0	80%
Jerry		3	1,302.0	1,308.0	6.0	6.0	100%
62.0 ft. tot		4	1,308.0	1,315.0	7.0	5.0	71%
56.0 ft. recov		5	1,315.0	1,322.0	7.0	6.0	86%
90%		6	1,322.0	1,327.0	5.0	5.0	100%
		7	1,327.0	1,337.0	10.0	10.0	100%
		8	1,337.0	1,347.0	10.0	9.0	90%
58	N	1	1,347.0	1,352.0	5.0	1.5	30%
		2	1,352.0	1,360.5	8.5	8.5	100%
Bill		3	1,360.5	1,363.0	2.5	0.5	20%
36.0 ft. tot		Trip for bit					
24.5 ft. recov		4	1,363.0	1,368.0	5.0	3.0	60%
68%		5	1,368.0	1,373.0	5.0	2.5	50%
		6	1,373.0	1,380.0	7.0	5.5	79%
		7	1,380.0	1,383.0	3.0	3.0	100%
59	D	Trip for broken wireline					
Jerry		1	1,383.0	1,389.0	6.0	6.0	100%
35.0 ft. tot		2	1,389.0	1,399.0	10.0	10.0	100%
34.0 ft. recov		3	1,399.0	1,407.0	8.0	8.0	100%
97%		4	1,407.0	1,418.0	11.0	10.0	91%
59	N	1	1,418.0	1,424.0	6.0	3.5	58%
Bill		2	1,424.0	1,431.0	7.0	7.0	100%
57.5 ft. tot		3	1,431.0	1,438.0	7.0	5.0	71%
48.7 ft. recov		4	1,438.0	1,447.0	9.0	8.0	89%

SOH-4
101mm core

Day	Shift	Run	Depth From	Depth To	Footage Cored	Footage Recovered	Percent Recovery
85%		5	1,447.0	1,450.0	3.0	2.5	83%
		6	1,450.0	1,460.5	10.5	10.2	97%
		7	1,460.5	1,471.0	10.5	10.0	95%
		8	1,471.0	1,475.5	4.5	2.5	56%
60	D	1	1,475.5	1,486.0	10.5	3.5	33%
Jerry		2	1,486.0	1,488.0	2.0	1.0	50%
43.5 ft. tot		3	1,488.0	1,498.0	10.0	9.0	90%
31.5 ft. recov		4	1,498.0	1,503.0	5.0	2.5	50%
72%		5	1,503.0	1,507.5	4.5	4.0	89%
		6	1,507.5	1,516.0	8.5	8.5	100%
		7	1,516.0	1,519.0	3.0	3.0	100%
		Pull rods for bit change					
60	N	Change bit, run in hole					
Bill		1	1,519.0	1,527.5	8.5	8.5	100%
44.5 ft. tot		2	1,527.5	1,531.5	4.0	1.5	38%
35.5 ft. recov		3	1,531.5	1,535.5	4.0	1.0	25%
80%		4	1,535.5	1,541.0	5.5	5.5	100%
		5	1,541.0	1,550.0	9.0	7.0	78%
		6	1,550.0	1,558.0	8.0	7.0	88%
		7	1,558.0	1,563.5	5.5	5.0	91%
61	D	1	1,563.5	1,572.0	8.5	7.0	82%
Jerry		2	1,572.0	1,582.0	10.0	10.0	100%
54.5 ft. tot		3	1,582.0	1,592.0	10.0	9.0	90%
52.0 ft. recov		4	1,592.0	1,596.0	4.0	4.0	100%
95%		5	1,596.0	1,605.0	9.0	9.0	100%
		6	1,605.0	1,614.0	9.0	9.0	100%
		7	1,614.0	1,618.0	4.0	4.0	100%
61	N	1	1,618.0	1,625.0	7.0	7.0	100%
Bill		2	1,625.0	1,631.0	6.0	3.5	58%
55.0 ft. tot		3	1,631.0	1,640.0	9.0	9.0	100%
47.5 ft. recov		4	1,640.0	1,646.0	6.0	4.0	67%
86%		5	1,646.0	1,650.0	4.0	3.0	75%
		6	1,650.0	1,655.0	5.0	4.5	90%
		7	1,655.0	1,663.0	8.0	6.5	81%
		8	1,663.0	1,673.0	10.0	10.0	100%
62	D	Trip for bit change					
Jerry		1	1,673.0	1,682.0	9.0	9.0	100%
38.0 ft. tot		2	1,682.0	1,692.0	10.0	9.0	90%
36.0 ft. recov		3	1,692.0	1,700.0	8.0	8.0	100%
95%		4	1,700.0	1,711.0	11.0	10.0	91%
62	N	1	1,711.0	1,721.0	10.0	10.0	100%
Bill		2	1,721.0	1,732.0	11.0	9.0	82%
58.0 ft. tot		3	1,732.0	1,739.0	7.0	5.0	71%

SOH-4
101mm core

Day	Shift	Run	Depth From	Depth To	Footage Cored	Footage Recovered	Percent Recovery
51.0 ft. recov		4	1,739.0	1,749.0	10.0	9.0	90%
88%		5	1,749.0	1,753.0	4.0	4.0	100%
		6	1,753.0	1,760.0	7.0	6.0	86%
		7	1,760.0	1,769.0	9.0	8.0	89%
63	D	Trip for bit change					
Jerry		1	1,769.0	1,777.0	8.0	8.0	100%
43.0 ft. tot		2	1,777.0	1,779.0	2.0	1.5	75%
35.5 ft. recov		3	1,779.0	1,782.5	3.5	2.0	57%
83%		4	1,782.5	1,792.0	9.5	9.5	100%
		5	1,792.0	1,800.0	8.0	6.0	75%
		6	1,800.0	1,806.0	6.0	3.5	58%
		7	1,806.0	1,812.0	6.0	5.0	83%
63	N	Trip for mislatch					
Bill		1	1,812.0	1,822.0	10.0	8.5	85%
26.5 ft. tot		2	1,822.0	1,829.0	7.0	5.0	71%
22.5 ft. recov		3	1,829.0	1,832.0	3.0	2.5	83%
85%		4	1,832.0	1,838.5	6.5	6.5	100%
64	D	Repair hydraulic leak					
Mike		1	1,838.5	1,844.0	5.5	5.5	100%
27.5 ft. tot		2	1,844.0	1,851.0	7.0	6.5	93%
25.5 ft. recov		3	1,851.0	1,856.0	5.0	4.5	90%
93%		4	1,856.0	1,863.0	7.0	7.0	100%
		5	1,863.0	1,866.0	3.0	2.0	67%
64	N	1	1,866.0	1,871.0	5.0	4.5	90%
Bill		2	1,871.0	1,877.5	6.5	6.0	92%
54 ft. tot		3	1,877.5	1,881.5	4.0	3.5	88%
51.8 ft. recov		4	1,881.5	1,889.0	7.5	7.5	100%
96%		5	1,889.0	1,899.0	10.0	10.0	100%
		6	1,899.0	1,910.0	11.0	10.3	94%
		7	1,910.0	1,920.0	10.0	10.0	100%
65	D	1	1,920.0	1,931.0	11.0	10.5	95%
Mike		2	1,931.0	1,941.0	10.0	10.0	100%
66.0 ft. tot		3	1,941.0	1,951.0	10.0	10.0	100%
65.5 ft. recov		4	1,951.0	1,961.0	10.0	10.0	100%
99%		5	1,961.0	1,971.5	10.5	10.5	100%
		6	1,971.5	1,976.0	4.5	4.5	100%
		7	1,976.0	1,986.0	10.0	10.0	100%
65	N	1	1,986.0	1,995.0	9.0	8.0	89%
Bill		2	1,995.0	2,000.0	5.0	5.0	100%
14.0 ft. tot		Trip out, run dev. survey					
13.0 ft. recovery							
93%							

Table 5

SOH-4
Core Bits

Bit #	Size	S.N.	Date On	On	Off	Ft. Cut	Remarks
1	134	L-39646	12-13-89	0	112	112	
2	101	L-41373	1-6-90	122	342	220	
3	101	SB11371-1	1-7-90	342	438	96	
4	101	SB17538-5	1-8-90	438	572	134	
5	101	SB17537-3	1-9-90	572	667	95	
6	101	SB17537-6	1-9-90	667	757	90	
7	101	SB17537-2	1-10-90	757	925	168	
8	101	SB17538-1	1-11-90	925	955	30	
9	101	SB17538-4	1-11-90	955	1,007	52	
10	134	L-39647	1-25-90	374	377	3	Ruined fishing
11	101	17700-4	2-17-90	1007	1093	86	
12	101	L-62341	2-18-90	1093	1266	173	
13	101	L-62342	2-20-90	1,266	1,363	97	
14	101	L-62339	2-21-90	1,363	1,519	156	
15	101	L-62338	2-23-90	1,519	1,673	154	
16	101	L-62337	2-25-90	1,673	1,812	139	
17	101	L-62340	2-26-90	1,812	2,000	188	
18	HQ	M6-23575	3-15-90	2,000	2,237	237	
19	HQ	M6-23573	3-18-90	2,237	2,660	423	
20	HQ	OR-157664	3-22-90	2,660	3,150	490	
21	HQ	SB-15648	3-27-90	3,150	3,490	340	
22	HQ	GP-71942	3-31-90	3,490	4,058	568	
23	HQ	M6-35649	4-7-90	4,058	4,731	673	
24	HQ	M6-356419	4-15-90	4,731	5,290	559	Lost w/ stuck rods
25	NQ	L-63175	4-26-90	5,290	5,648	358	
26	NQ	L-63178	5-2-90	5,648	6,402	754	
27	NQ	L-63181	5-13-90	6,402	6,562	160	TD bit, pulled early

Table 6
SOH-4 DRILLING EXPENDITURES

ACTIVITY	COST	SOH-4 % TOTAL
SITE & ROAD CONSTRUCTION	4,500	0.27%
MOB, PREP. & SET-UP	23,099	1.41%
RIG, LABOR, FOOTAGE CHG. & TAX	735,347	44.74%
RENTAL EUIPMENT	105,468	6.42%
BITS (core and rotary)	35,775	2.18%
MISC. DOWN HOLE EQUIP.	36,297	2.21%
MUDS	94,534	5.75%
WATER (trucking & county charges)	91,972	5.60%
CMT. & CMT SERVICES	36,029	2.19%
WELLHEAD, CASING & FLOAT EQUIP.	96,651	5.88%
BOP EQUIP. (Rental equipment)	29,693	1.81%
TRANSPORTATION	18,524	1.13%
MISC MATERIALS	8,577	0.52%
MISC LABOR & SERVICES	10,266	0.62%
SUPERVISION	58,800	3.58%
GEOPHYSICAL LOGGING	58,445	3.56%
OTHER	22,836	1.39%
TOTAL EXPENDITURES	1,466,813	

Figure 1
SOH-4
Completed Well Schematic

17.5" hole from surface - 114 ft.
13.375" K-55, 61#/ft casing
Cemented w/ redimix

12.25" hole from 114 - 992 ft.
9.625" K-55, 40#/ft casing
Cemented w/Class G high temp. cement

8.5" hole from 992 - 2,000 ft.
7" L-80, 35#/ft casing
Cemented w/ Class G high temp. cement

HQ hole (3.78" hole x 2.50" core)
2,000 - 5,290 ft.

750 ft. HQ core rods, outer barrel & HQ bit
left in hole. 4,530 - 5,290 ft.

NQ hole (2.98" hole x 1.875" core)
5,290 - 6,562 ft.

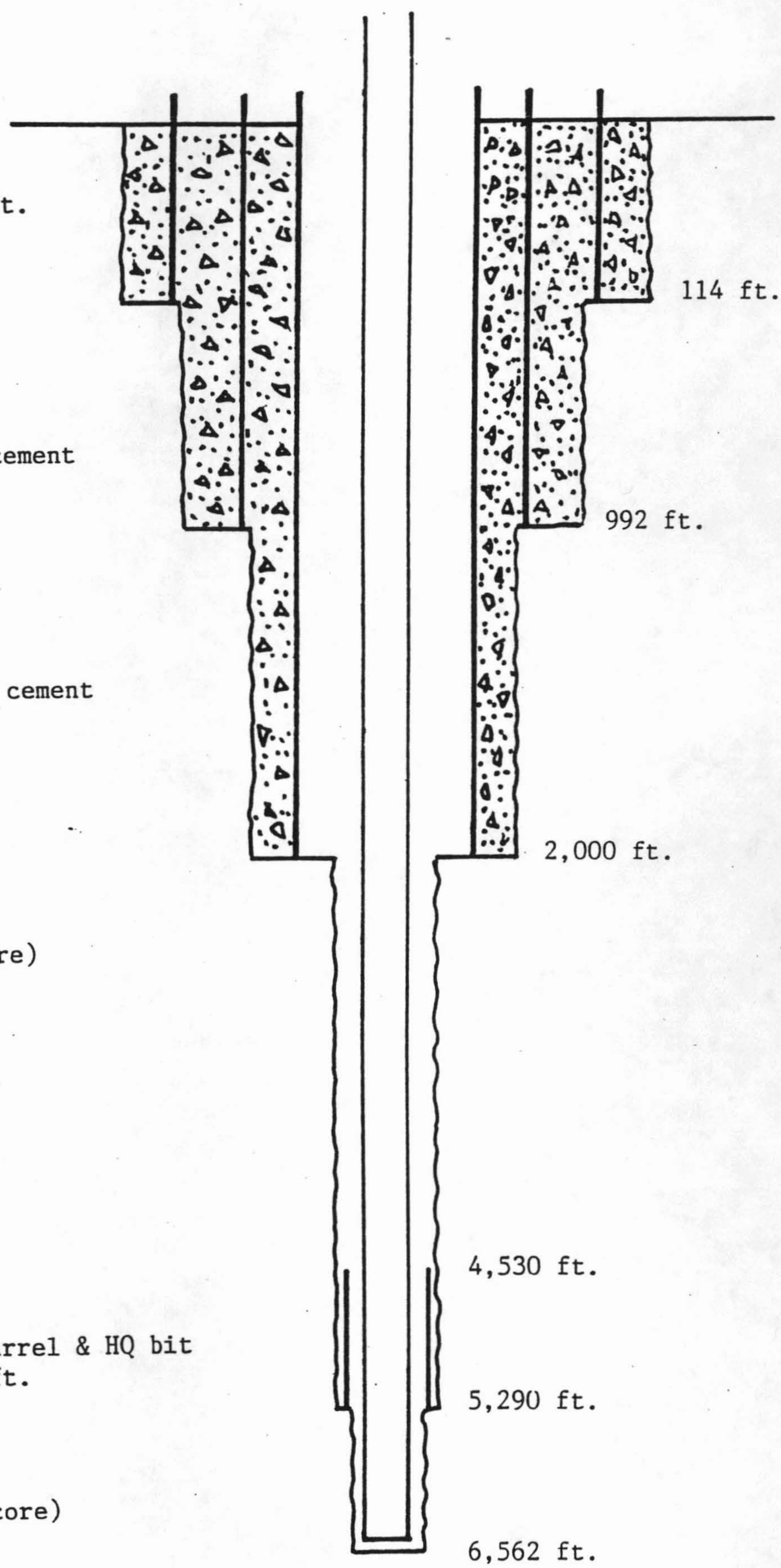
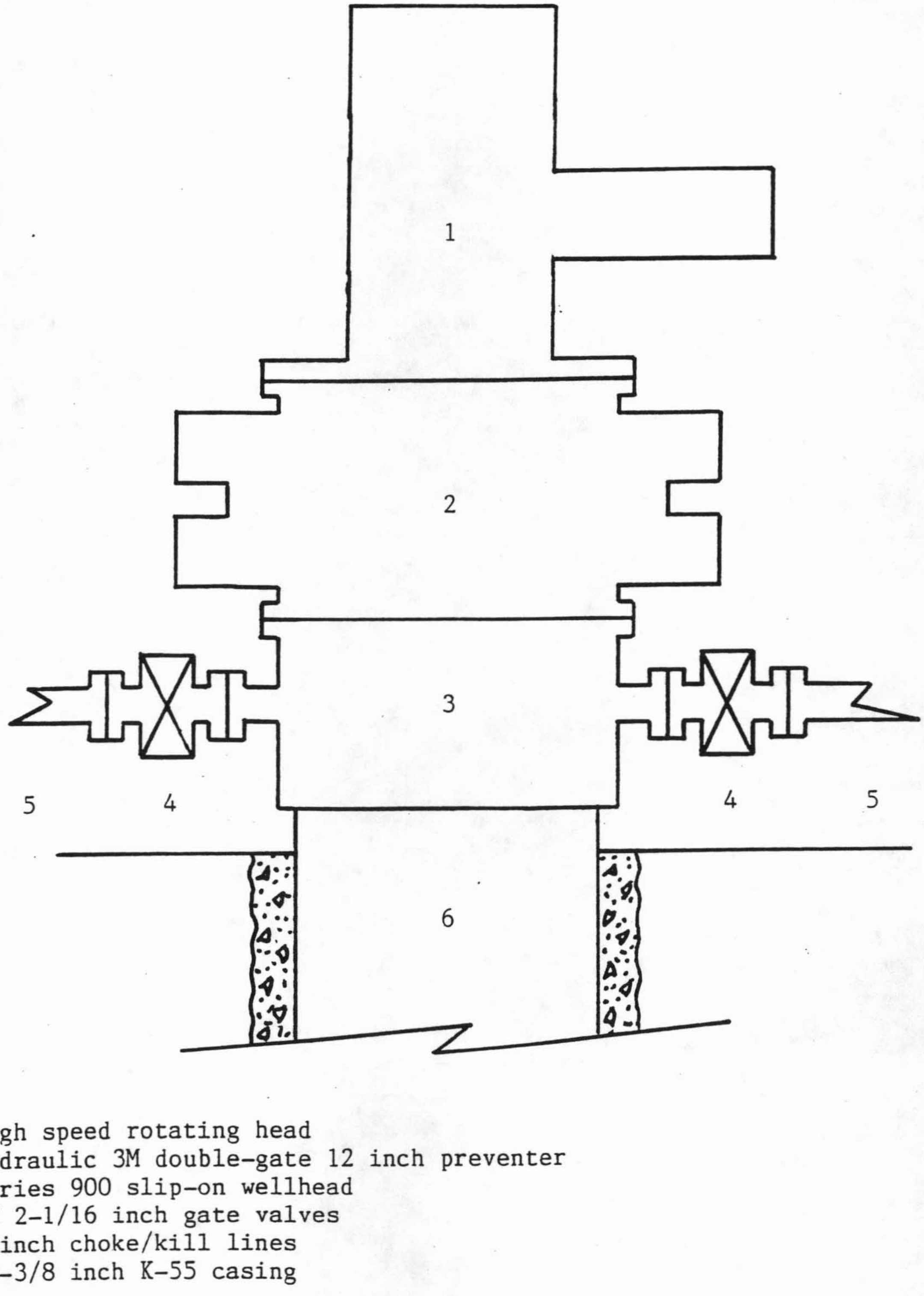
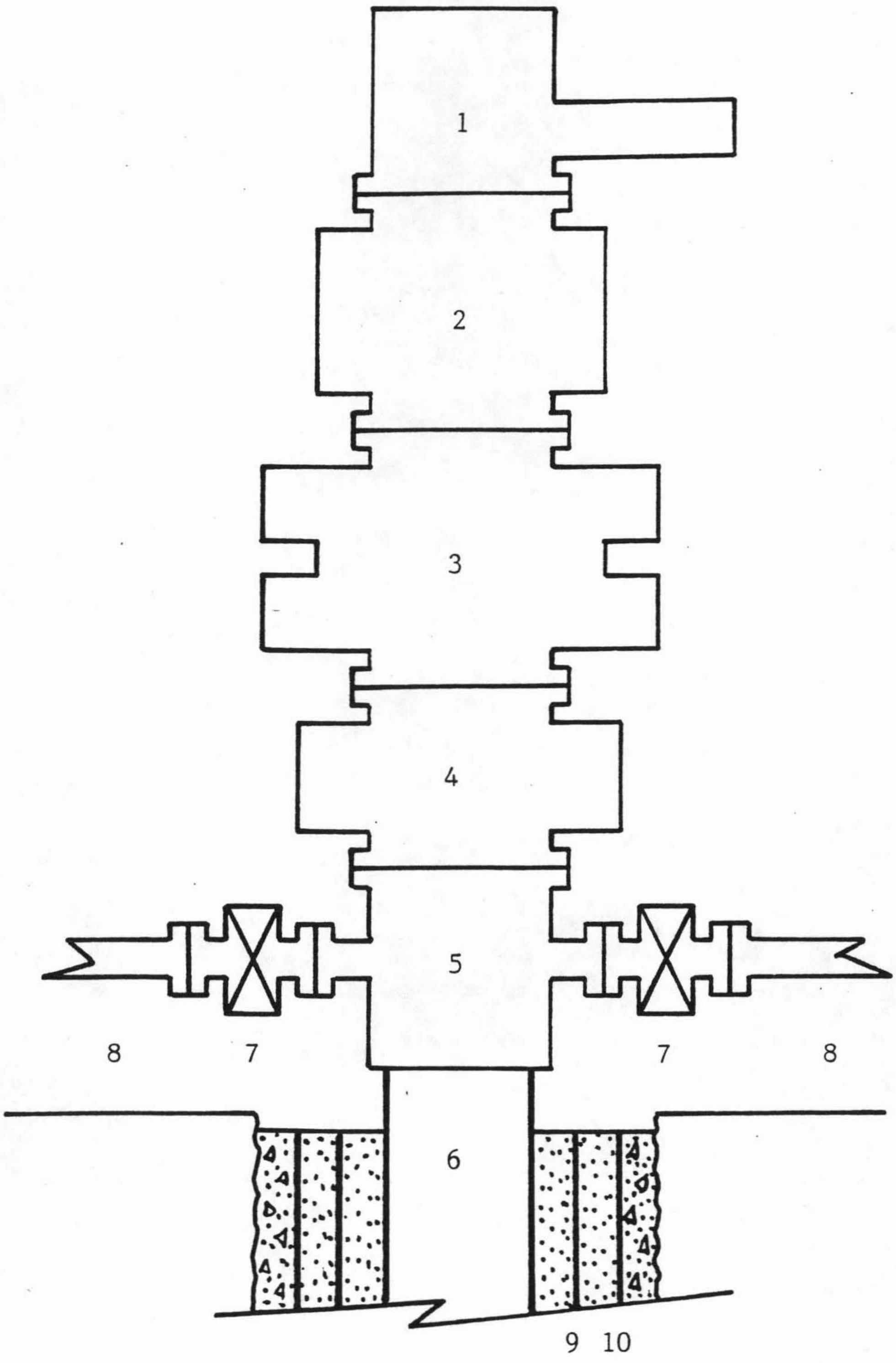


Figure 2
SOH-4
13-3/8" Wellhead



1. High speed rotating head
2. Hydraulic 3M double-gate 12 inch preventer
3. Series 900 slip-on wellhead
4. 3M 2-1/16 inch gate valves
5. 2 inch choke/kill lines
6. 13-3/8 inch K-55 casing

Figure 3
SOH-4
7 Inch Wellhead



1. High speed rotating head
2. 6 inch annular preventer
3. Hydraulic 3M double-gate
4. 6 inch 3M gate valve
5. Series 900 7 inch slip on wellhead
6. 7 inch L-80 casing
7. 2-1/16" 3M gate valves
8. 2 inch choke/kill lines
9. 9-5/8" K-55 casing
10. 13-3/8" K-55 casing

Figure 4

SOH-4 Completion Wellhead

1. 2" Ball Valve
2. 2" Nipple
3. Companion Flange - 2-2/16" 3M x 3" L.P.
4. Gate Valve - 2-9/16" Foster Flow-Seal w/ T-24 trim
5. Tubing Head Adapter - 7-1/16" 3M x 2-9/16" 3M
6. 7" EFSO Wellhead
7. Gate Valves - 2-1/16" 3M Foster Flow-Seal w/ T-24 trim
8. Companion Flanges - 2-1/16" 3M x 2" L.P.
9. 7" L-80, 35#/ft. Casing
10. NQ Completion Tubing (2.75" O.D., 5.5#/ft.)
11. 9-5/8" K-55, 40#/ft. Casing
12. 13-3/8" K-55, 61#/ft. Casing

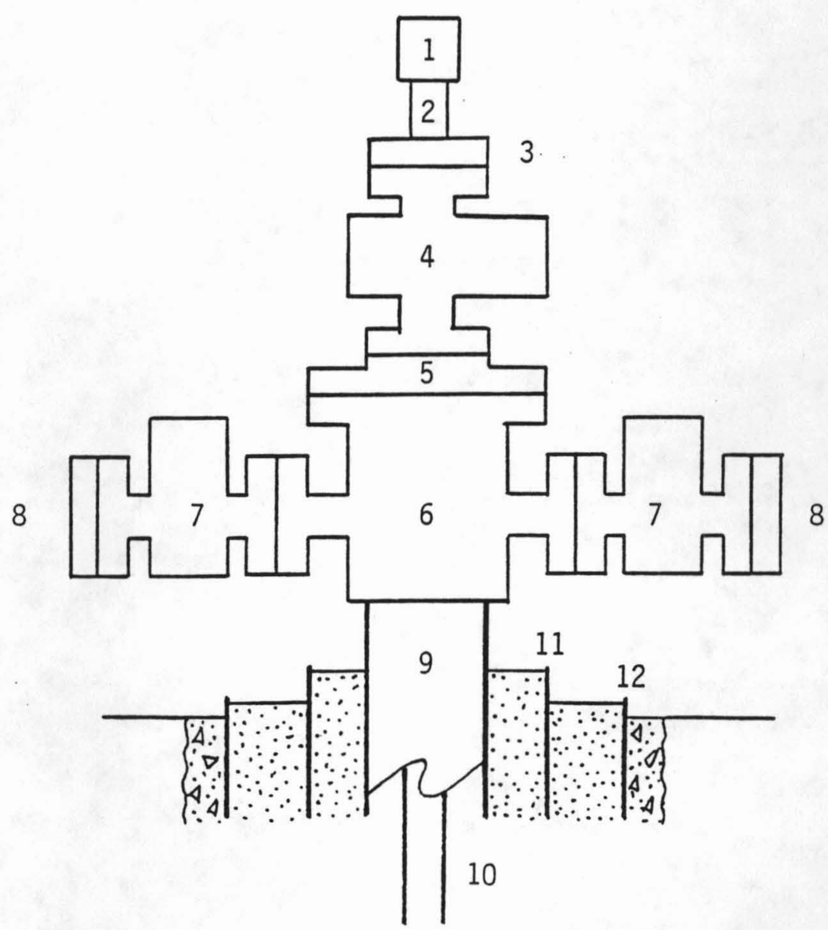
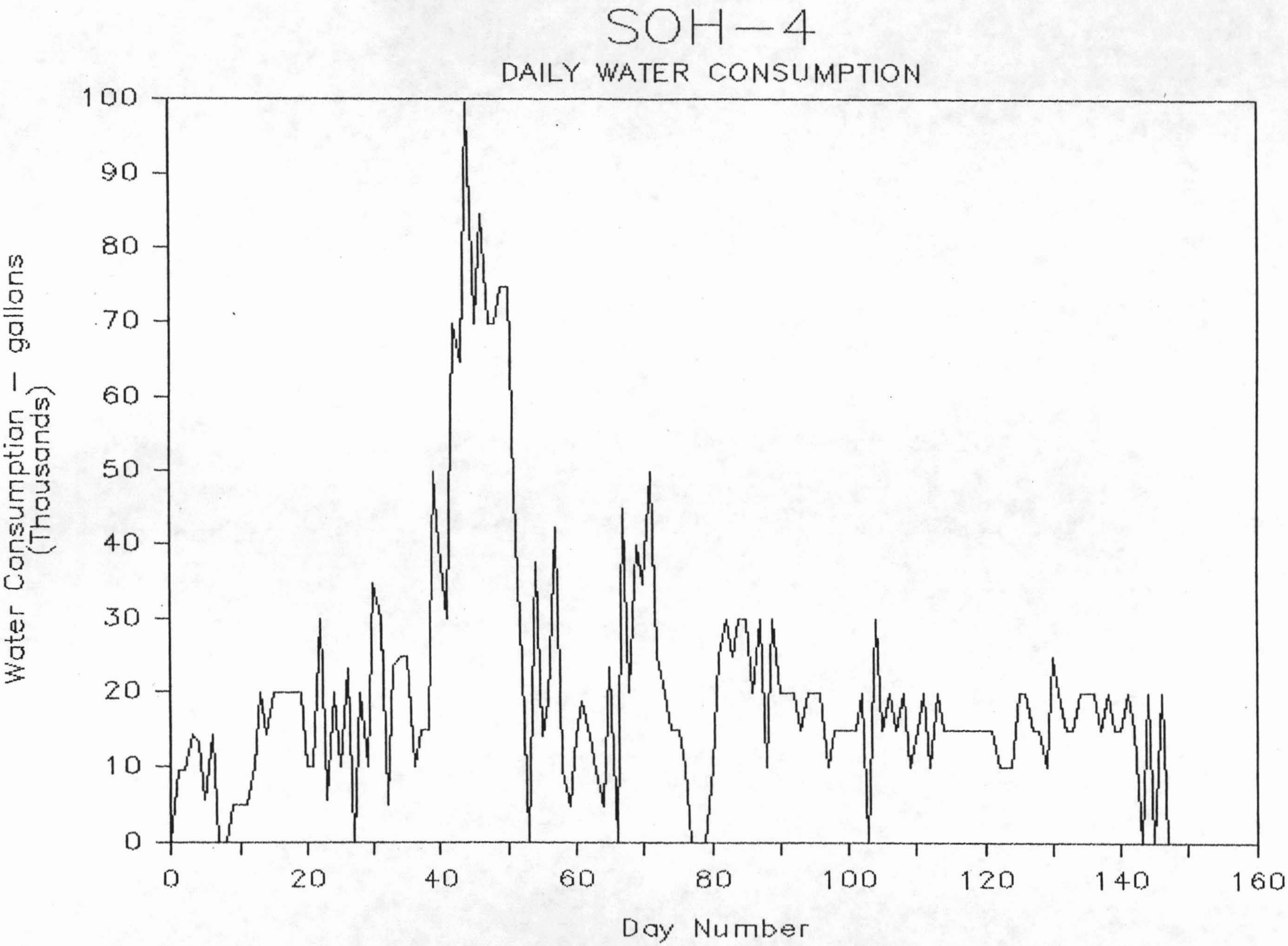


Figure 5



SOH—4
DAILY WATER CONSUMPTION
Water Consumption — gallons
(Thousands)
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
Day Number

Figure 6

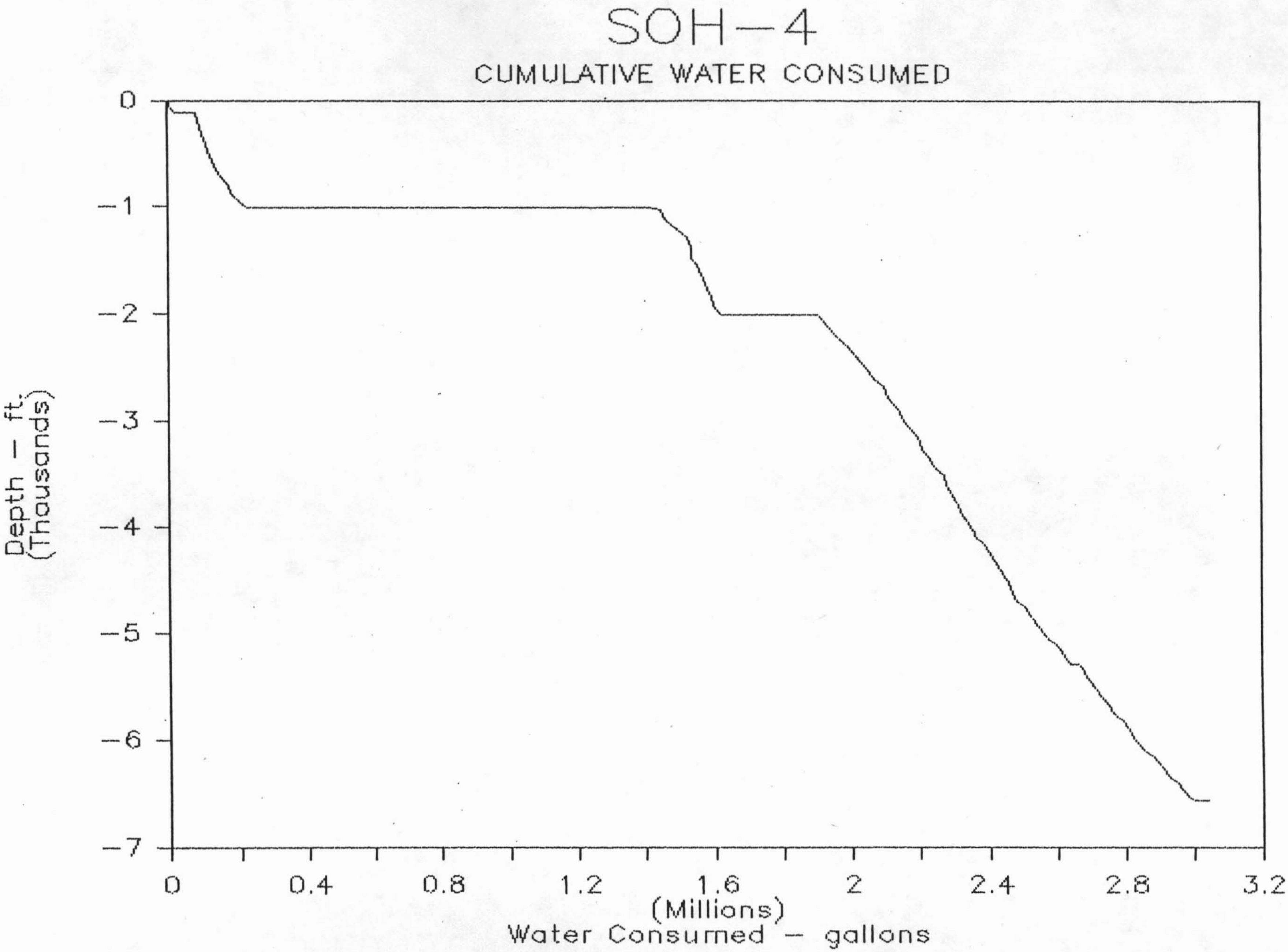
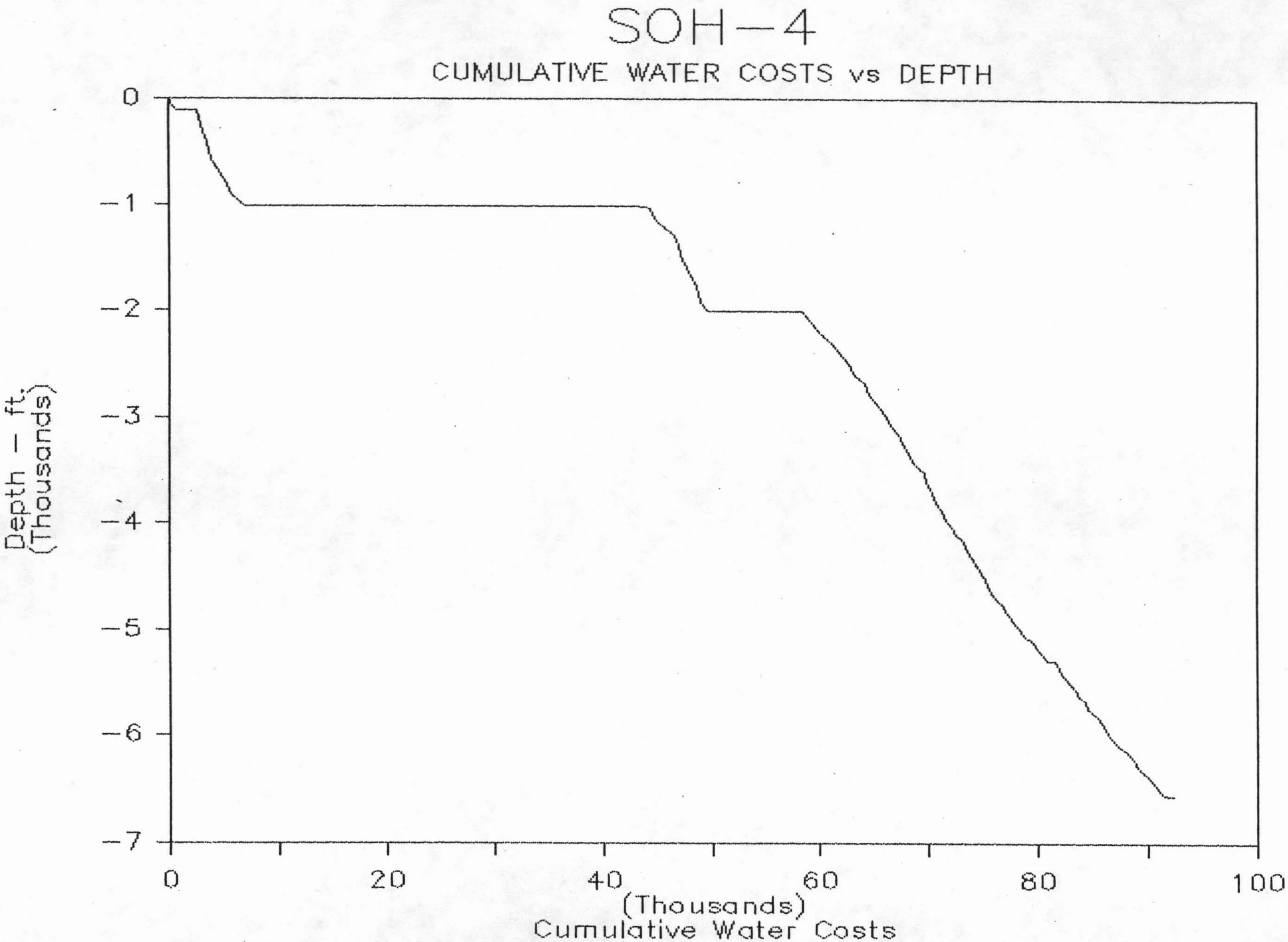

SOH-4
CUMULATIVE WATER CONSUMED
Depth - ft.
(Thousands)
0
-1
-2
-3
-4
-5
-6
-7
0
0.4
0.8
1.2
1.6
2
2.4
2.8
3.2
(Millions)
Water Consumed - gallons

Figure 7



SOH-4
CUMULATIVE WATER COSTS vs DEPTH
0
-1
-2
-3
-4
-5
-6
-7
Depth - ft.
(Thousands)
0
20
40
60
80
100
(Thousands)
Cumulative Water Costs

Figure 8

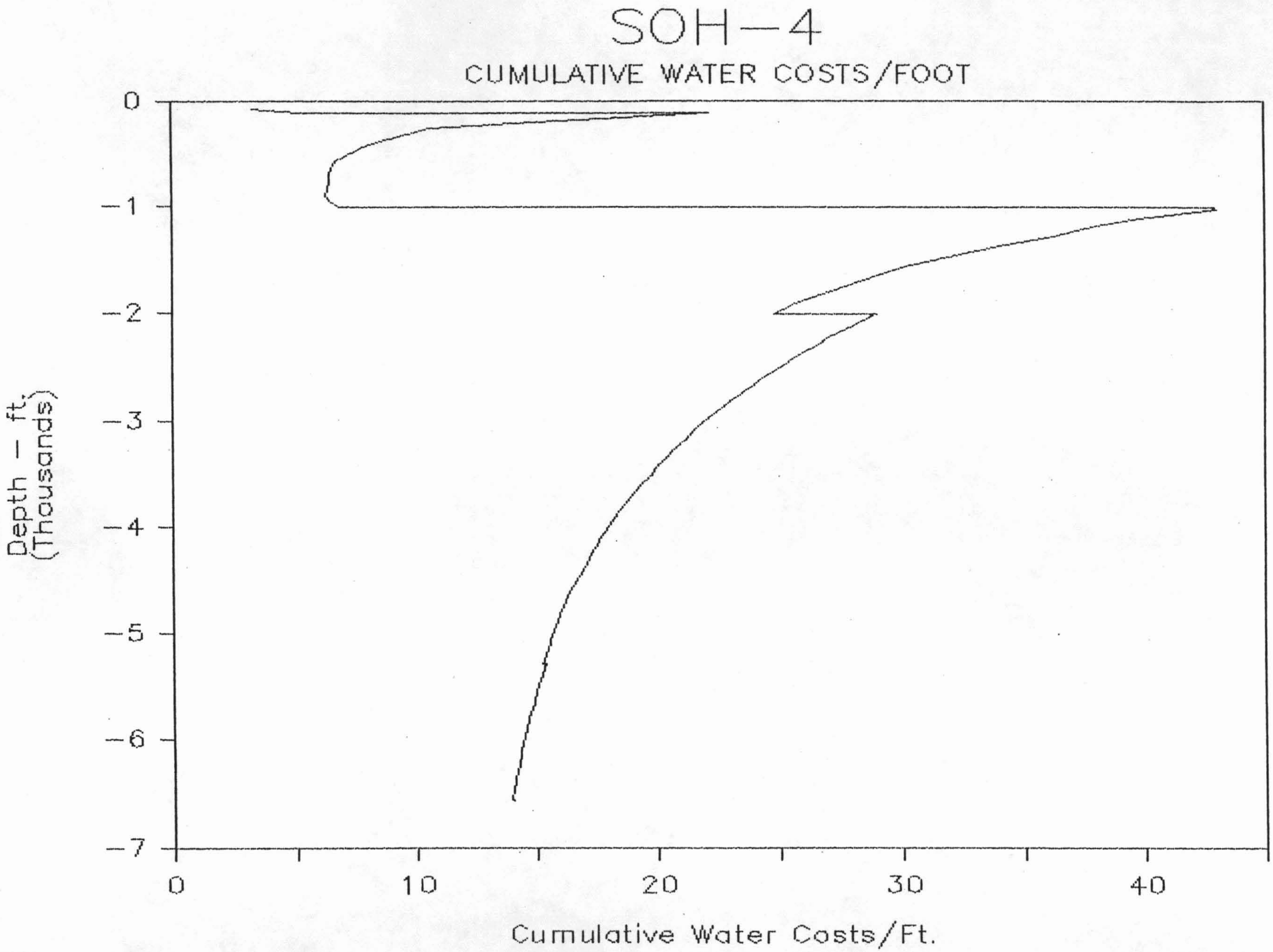
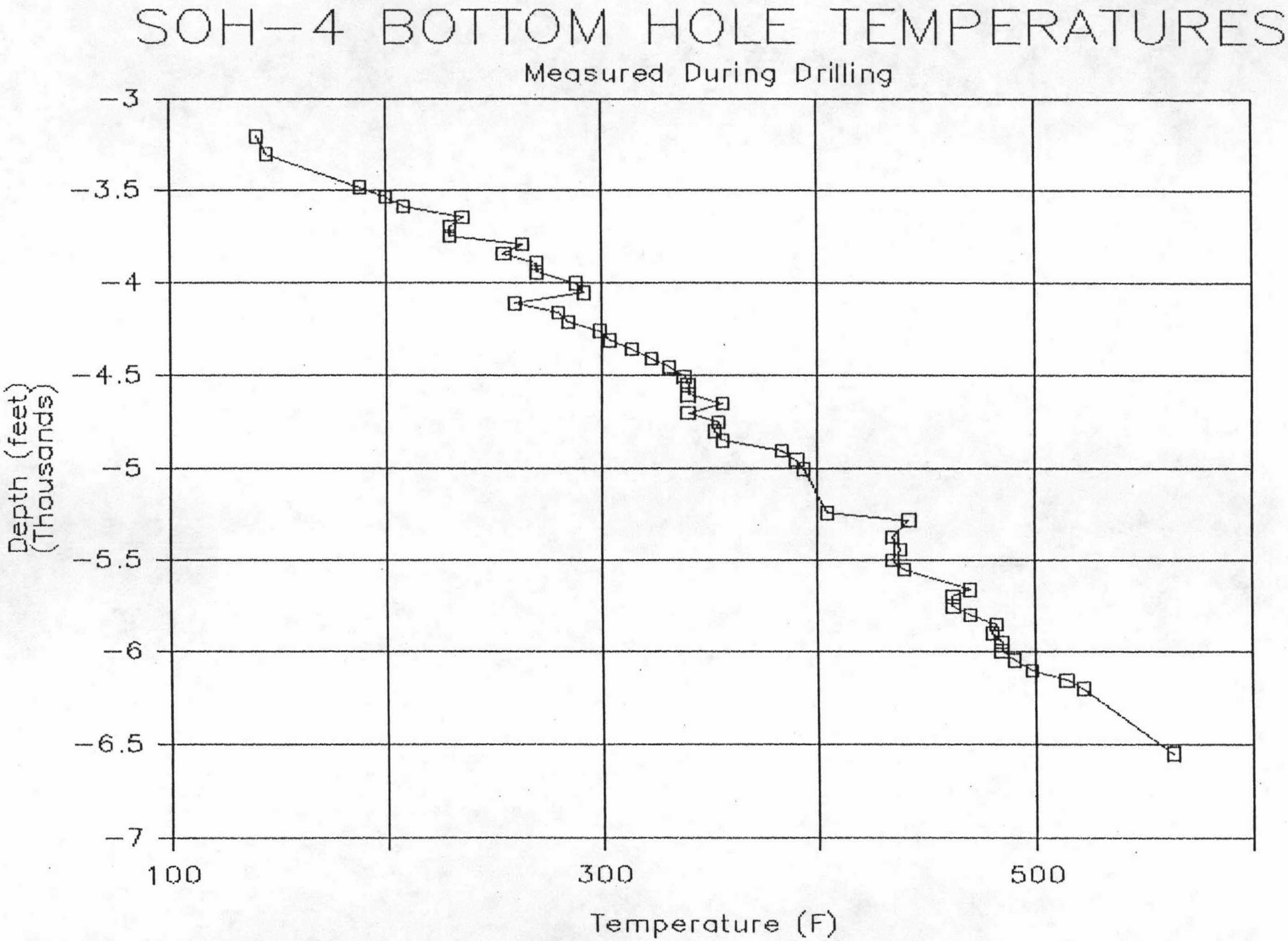

SOH-4
CUMULATIVE WATER COSTS/FOOT
Depth - ft, (Thousands)
0
-1
-2
-3
-4
-5
-6
-7
0
10
20
30
40
Cumulative Water Costs/Ft.

Figure 9



SOH-4 BOTTOM HOLE TEMPERATURES
Measured During Drilling
-3
-3.5
-4
-4.5
-5
-5.5
-6
-6.5
-7
Depth (feet)
(Thousands)
100
300
500
Temperature (F)

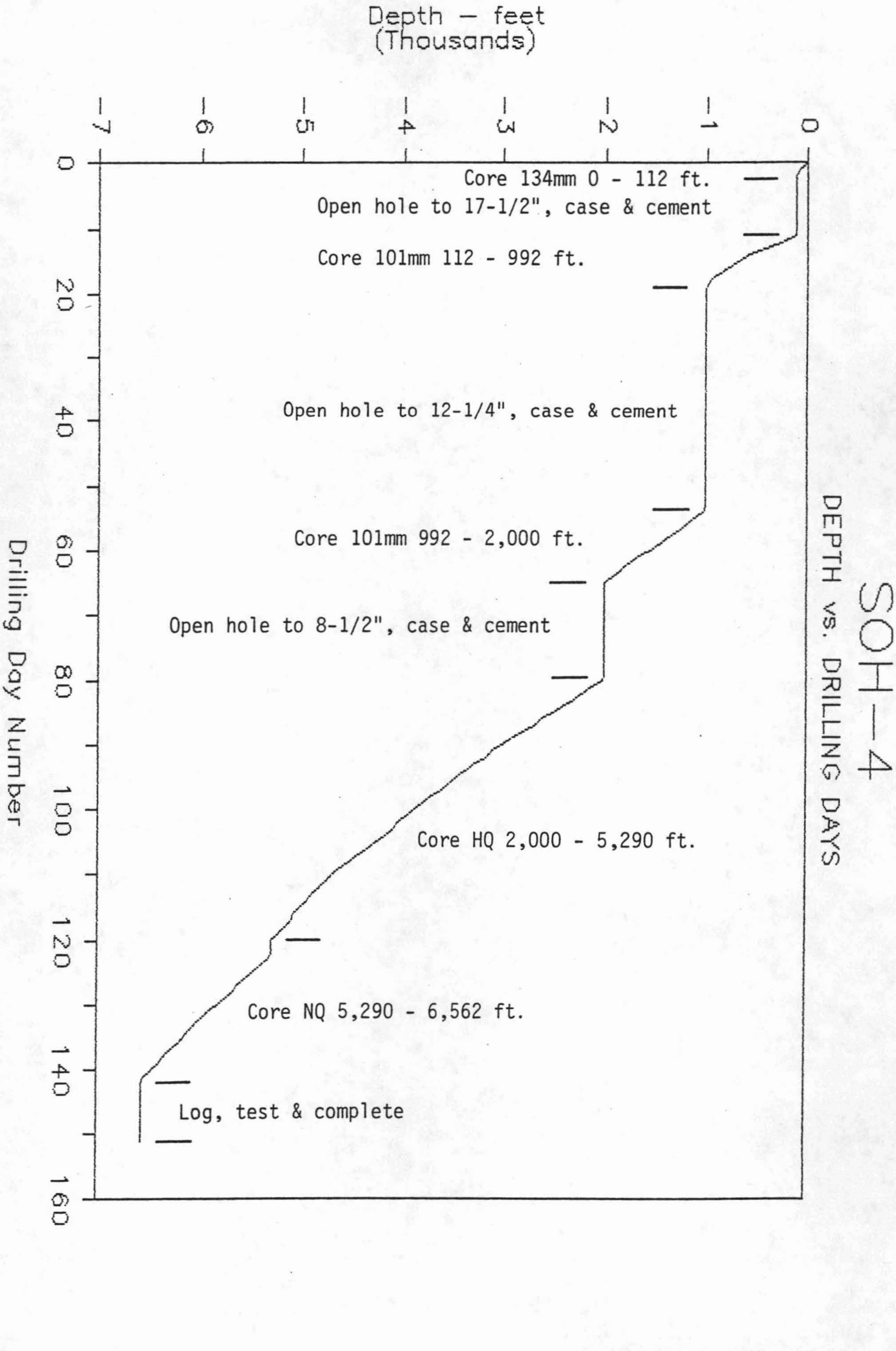
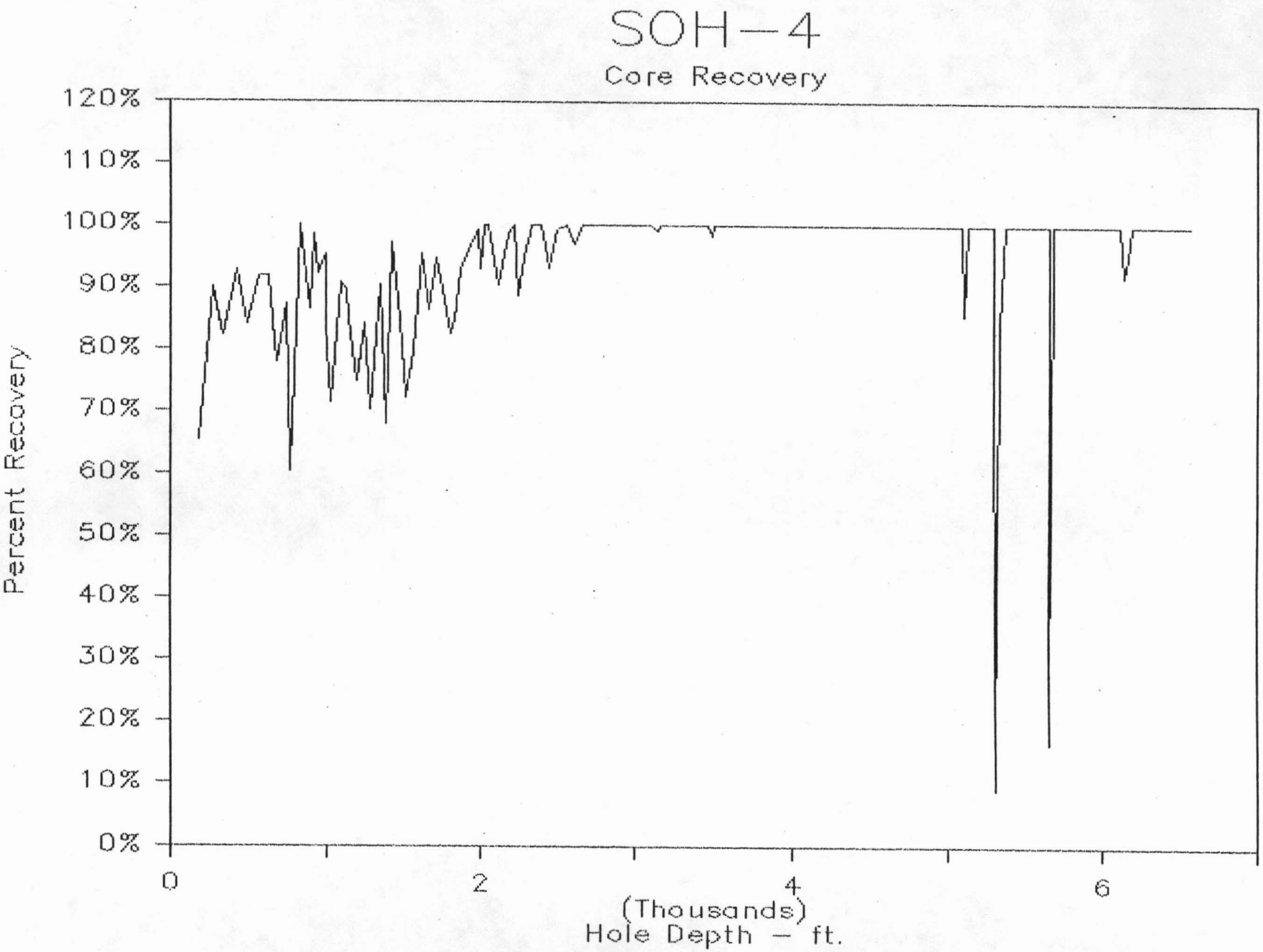

SOH-4
DEPTH vs. DRILLING DAYS
Depth — feet
(Thousands)
0
-1
-2
-3
-4
-5
-6
-7
Core 134mm 0 - 112 ft.
Open hole to 17-1/2", case & cement
Core 101mm 112 - 992 ft.
Open hole to 12-1/4", case & cement
Core 101mm 992 - 2,000 ft.
Open hole to 8-1/2", case & cement
Core HQ 2,000 - 5,290 ft.
Core NQ 5,290 - 6,562 ft.
Log, test & complete
0
20
40
60
80
100
120
140
160
Drilling Day Number

Figure 10

Figure 11


SOH-4
Core Recovery
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent Recovery
0
2
4
6
(Thousands)
Hole Depth - ft.

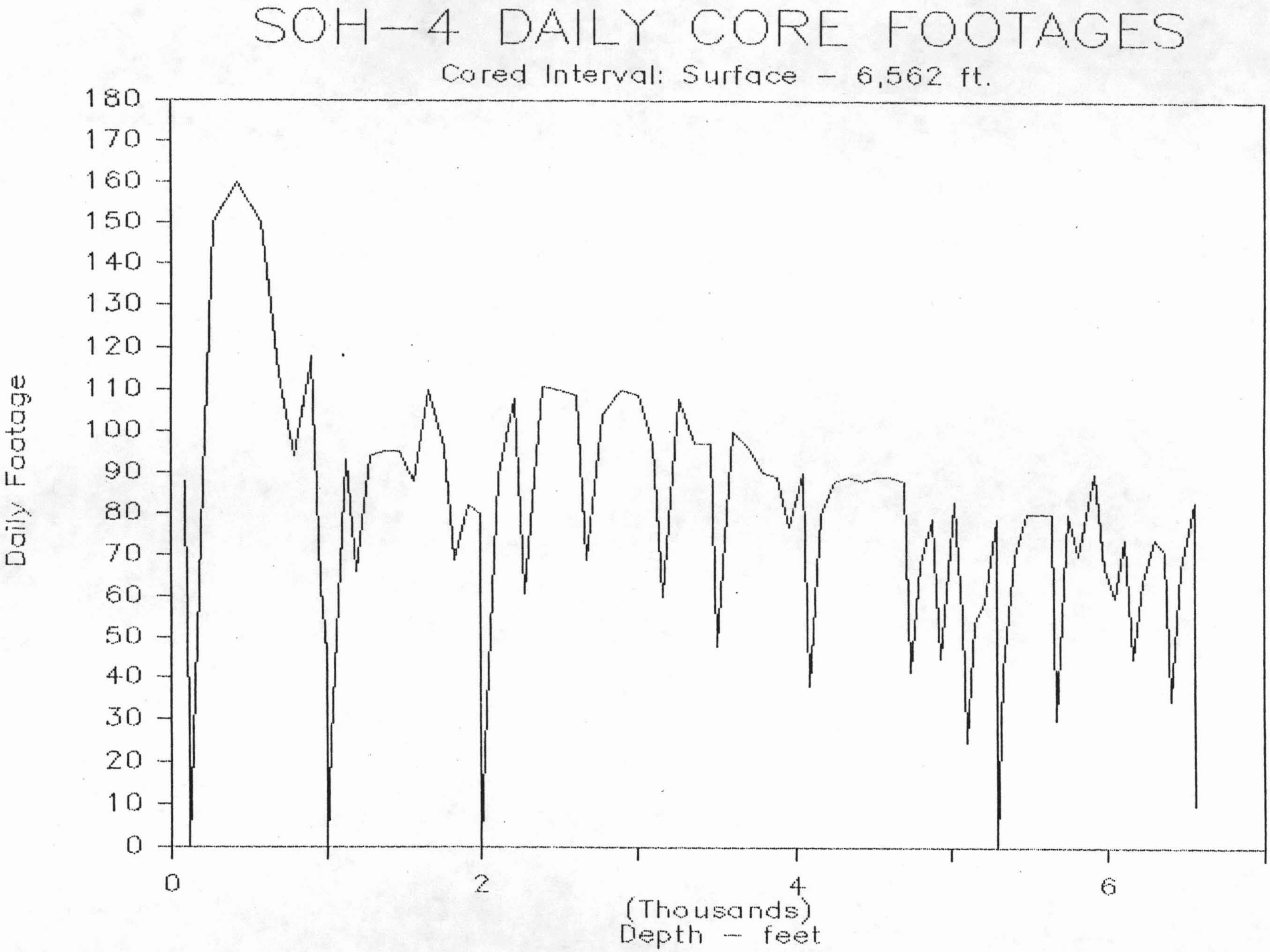
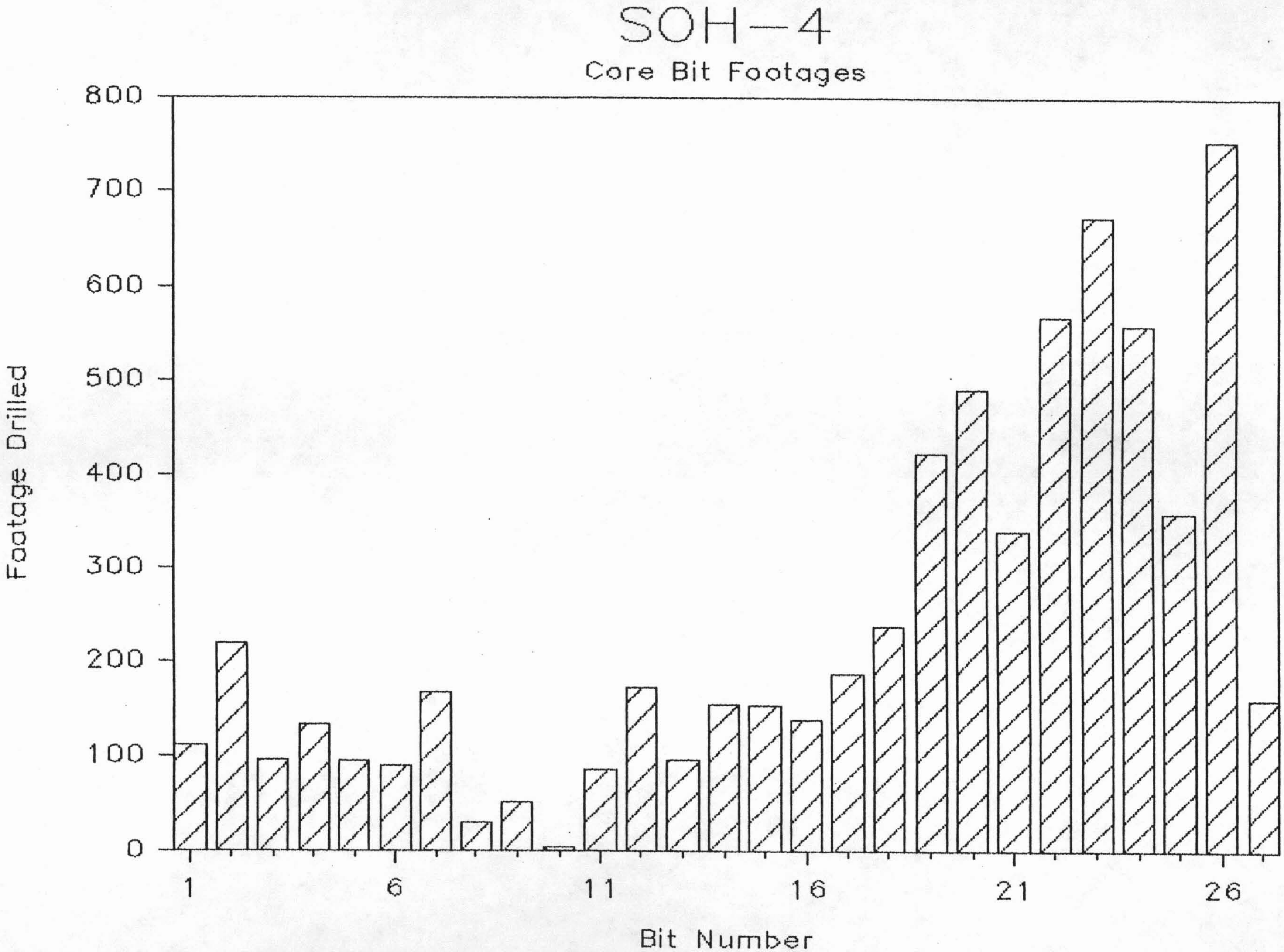
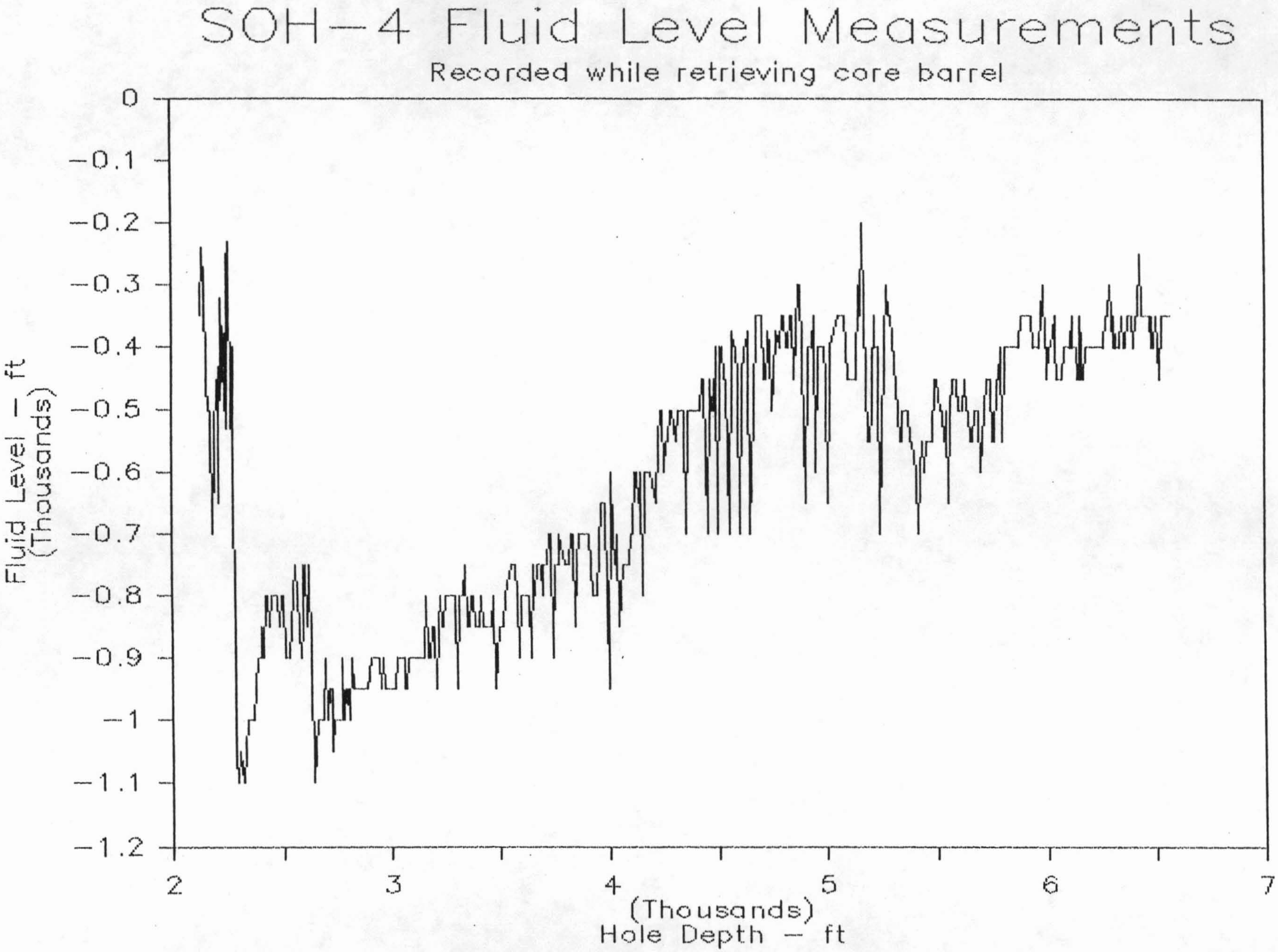

SOH—4 DAILY CORE FOOTAGES
Cored Interval: Surface — 6,562 ft.
Daily Footage
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
(Thousands)
Depth — feet

Figure 12

Figure 13


SOH−4
Core Bit Footages
800
700
600
500
400
300
200
100
0
Footage Drilled
1
6
11
16
21
26
Bit Number



SOH-4 Fluid Level Measurements
Recorded while retrieving core barrel
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
-1.2
Fluid Level - ft
(Thousands)
2
3
4
5
6
7
(Thousands)
Hole Depth - ft

Figure 14

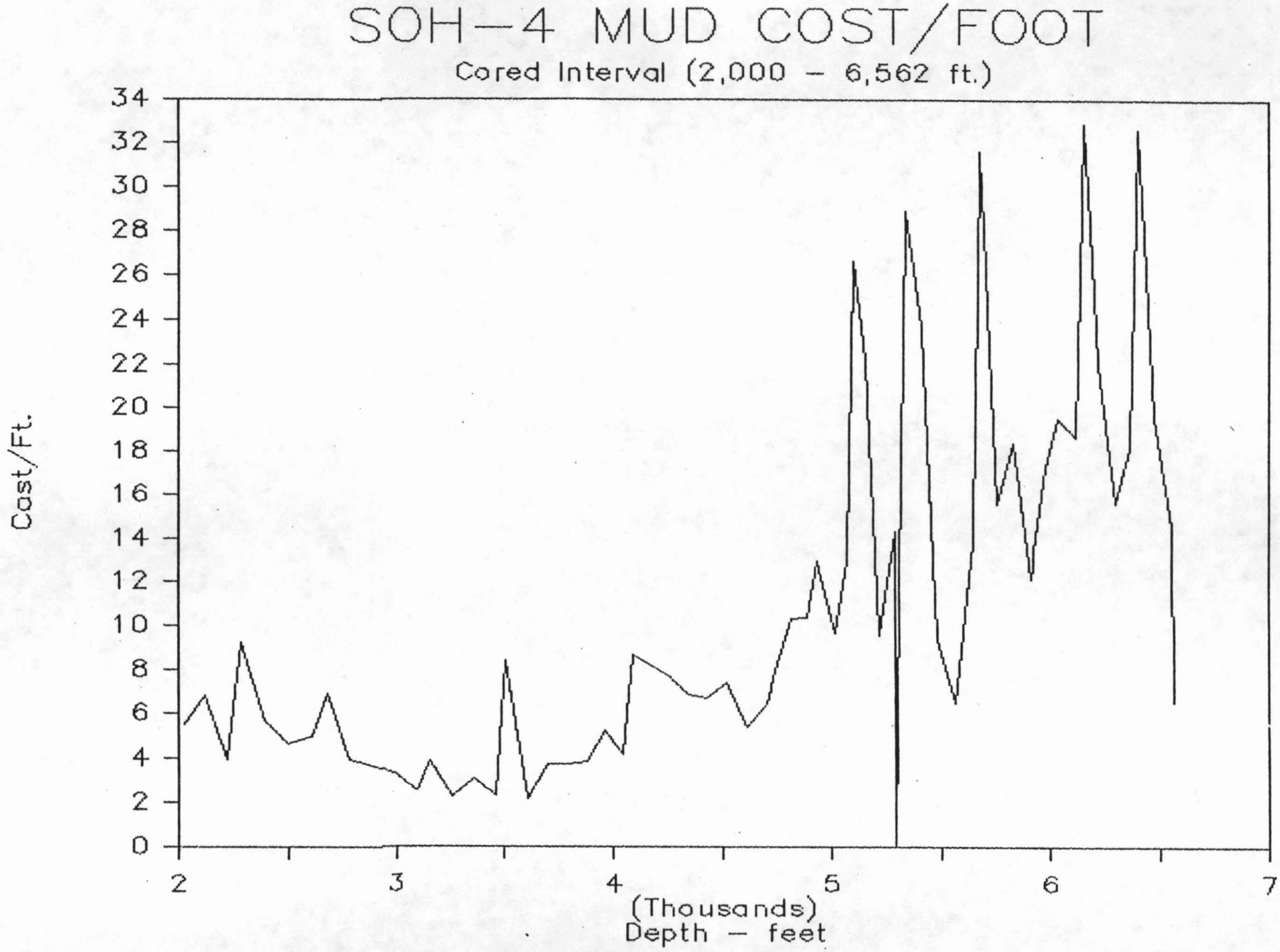

SOH—4 MUD COST/FOOT
Cored Interval (2,000 – 6,562 ft.)
Cost/Ft.
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
2
3
4
5
6
7
(Thousands)
Depth – feet

Figure 15

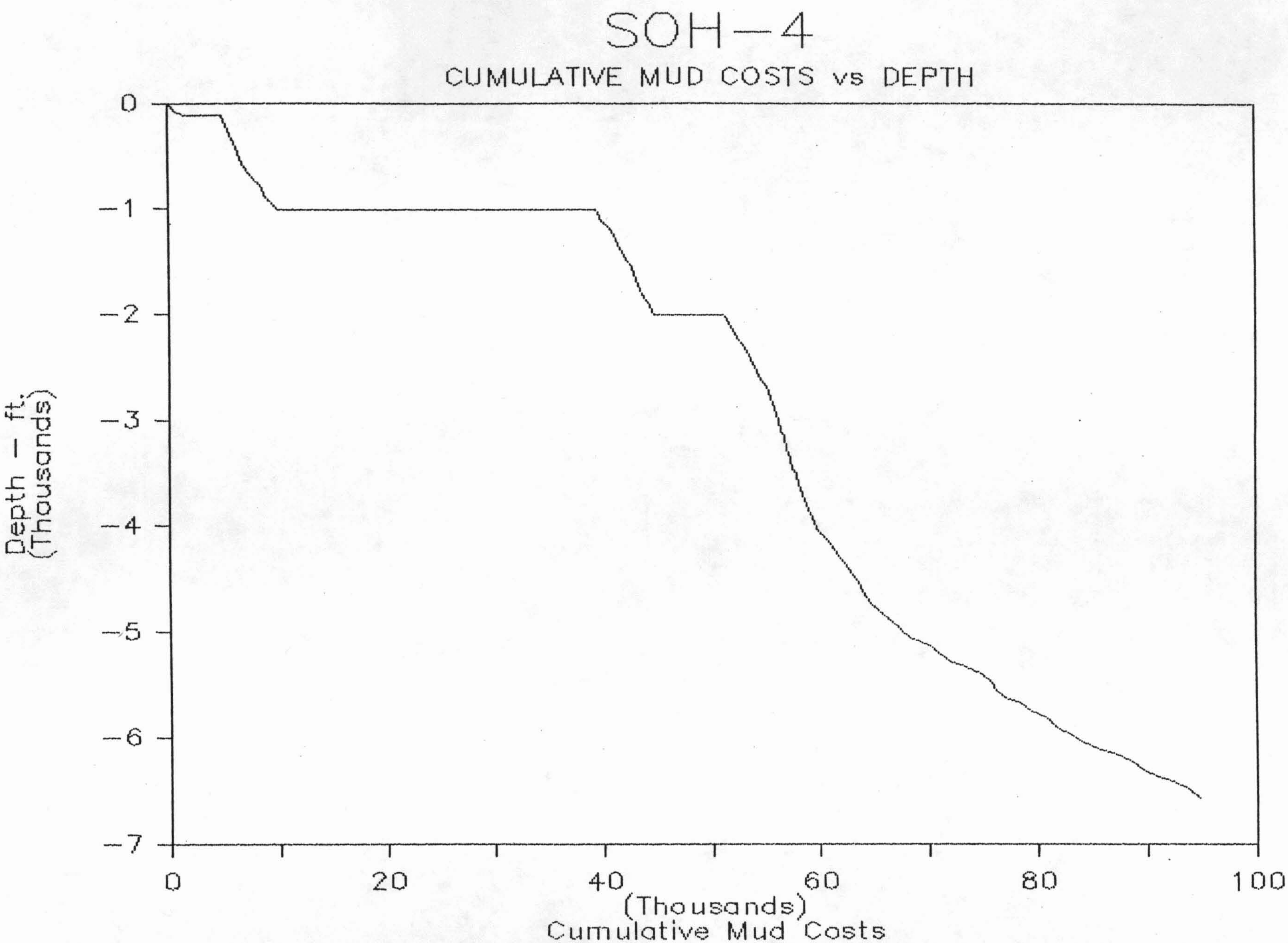

SOH-4
CUMULATIVE MUD COSTS vs DEPTH
Depth - ft.
(Thousands)
0
-1
-2
-3
-4
-5
-6
-7
0
20
40
60
80
100
(Thousands)
Cumulative Mud Costs

Figure 16

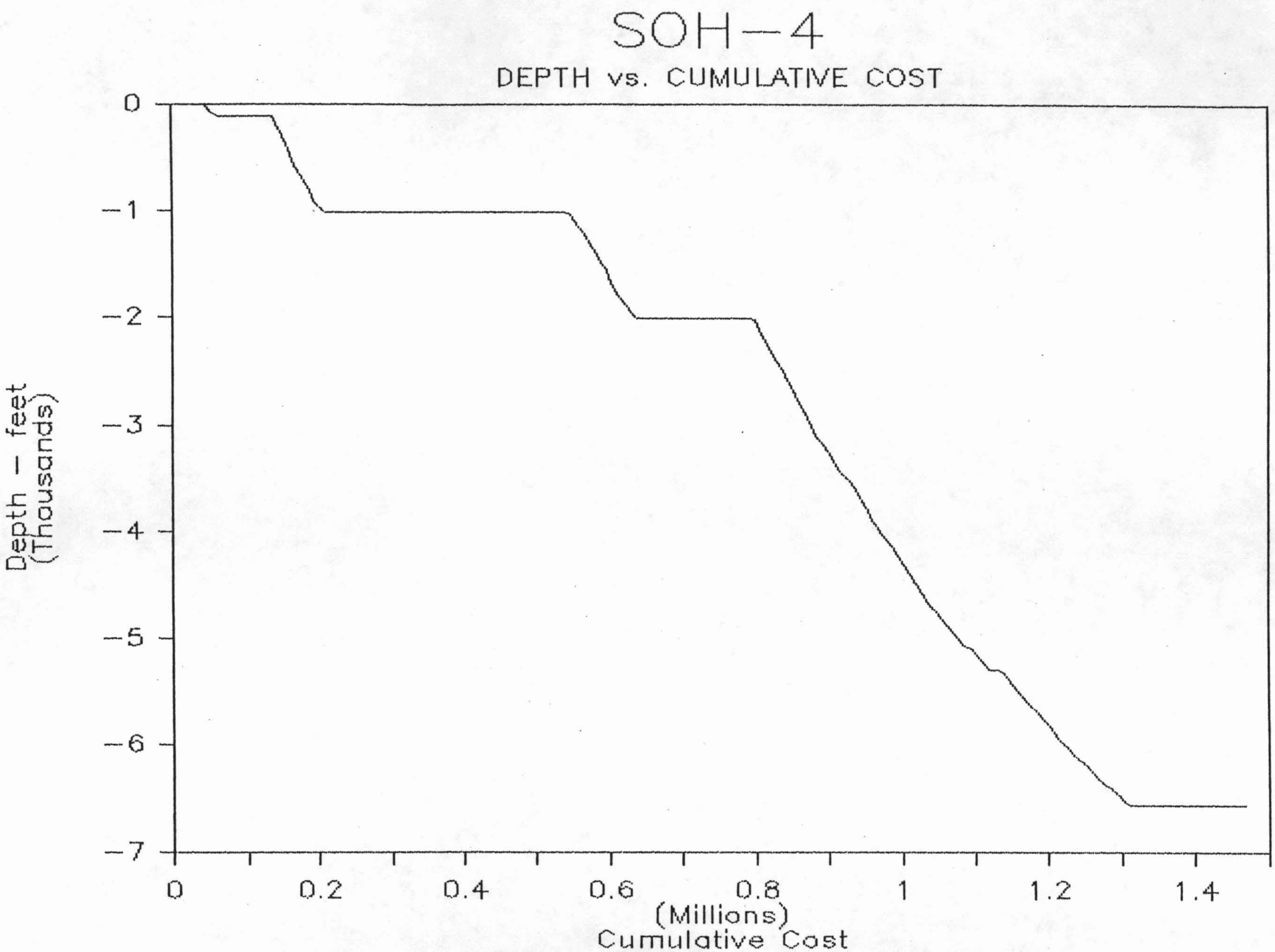
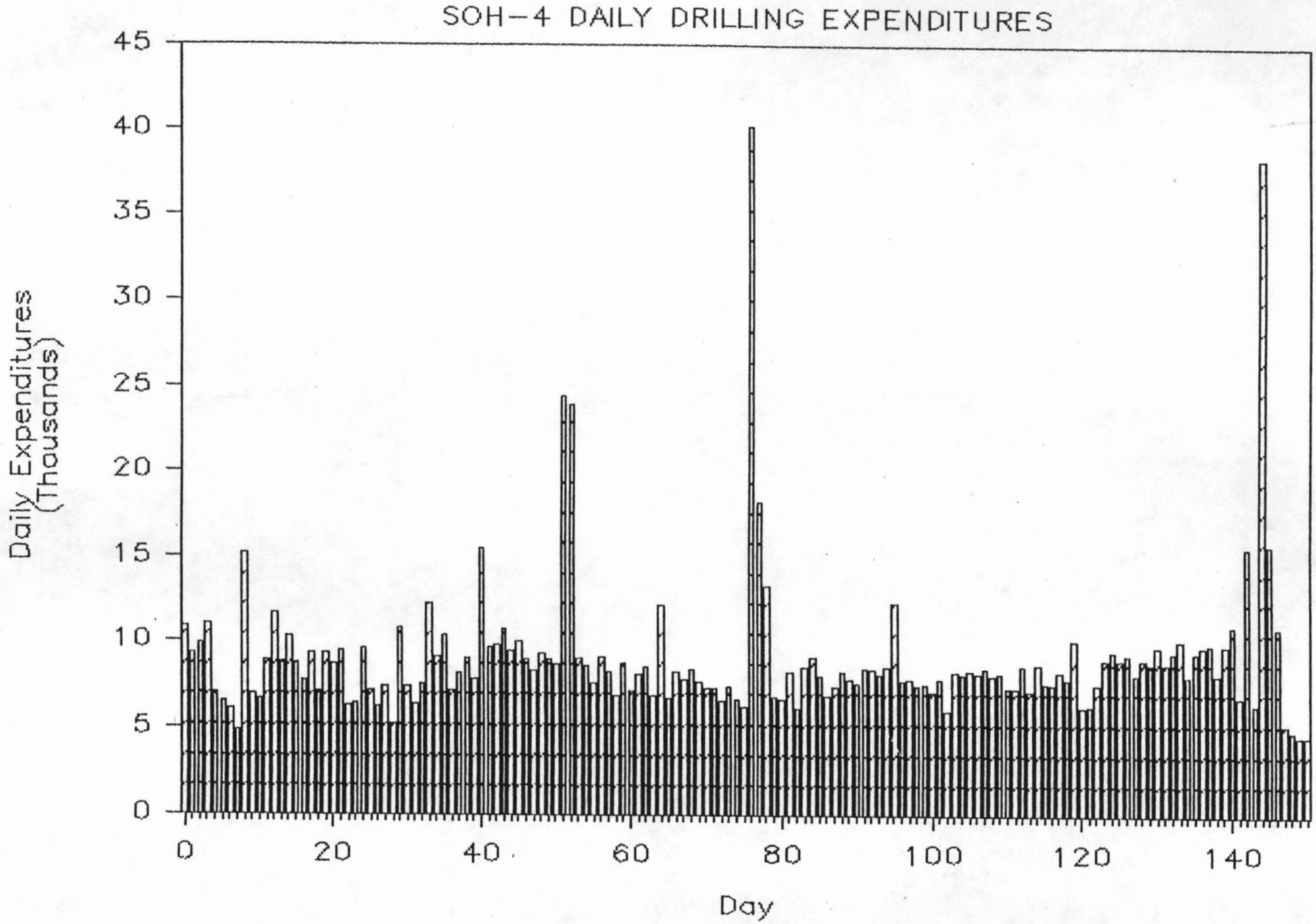

SOH-4
DEPTH vs. CUMULATIVE COST
Depth - feet
(Thousands)
0
-1
-2
-3
-4
-5
-6
-7
0
0.2
0.4
0.6
0.8
1
1.2
1.4
(Millions)
Cumulative Cost

Figure 17


SOH-4 DAILY DRILLING EXPENDITURES
45
40
35
30
25
20
15
10
5
0
Daily Expenditures
(Thousands)
0
20
40
60
80
100
120
140
Day
Figure 18